TEXTILE RESEARCH JOURNAL

Publication of

TEXTILE RESEARCH INSTITUTE

VOLUME XXIX SEPTEMBER 1959 NUMBER 9

TEXTILE RESEARCH JOURNAL

VOL. XXIX *September 1959* NUMBER 9

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TEXTILE RESEARCH JOURNAL, published monthly at Prince and Lemon Streets, Lancaster, Pa., is devoted to the interest of research in textile and allied industries. It is published by Textile Research Institute.

Manuscripts and communications should be sent to the Publications Department, P.O. Box 625, Princeton, N. J.

Second-class postage paid at Lancaster, Pa.

Subscription rates: $25.00 per year; additional for postage, 50 cents to Canada, $1.00 to all other countries. Single copies, $2.50 each.

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IN THIS ISSUE

Annual Meeting
Textile Research Institute

Thermal Effects in Tire Cord Materials. *J. O. Wood, R. S. Goy, and F. S. Daruwalla* 669

Polyolefin Fibers and Polymer Structure. *Victor L. Erlich* .. 679

Cotton Research Clinic
National Cotton Council

The Effect of the Short Fibers in a Cotton on its Processing Efficiency and Product Quality. Part I: Affecting the Short Fiber Content by the Addition of Cut Cotton Fibers. *John D. Tallant, Louis A. Fiori, and Dorothy C. Legendre* 687

A Method for Determining the Effects of Various Gin Treatments on the Spinnability of Cotton. *Samuel T. Burley, Jr.* 696

A Miniature Spinning Test for Cotton. *C. B. Landstreet, P. R. Ewald, and T. Kerr* 699

Blending Cottons Differing Widely in Maturity. Part I: Effect on Properties of Single Yarns. *Louis A. Fiori, Gain L. Louis, and Jack E. Sands* 706

Large Scale Commercial Blending. *Joel F. Hembree* 717

Massive Cotton Blending for Mill Production. *David E. Howe and Joe F. Mattison* 722

The Continuous Flow Cleaning Line. *Louis Platt* 727

Design of the SRRL Granular Card. *A. L. Miller and R. S. Brown* 733

Preliminary Mill Evaluation of the Southern Regional Research Laboratories Flatless Card. *G. P. Callaway* 737

The Control of Comber Noils. *J. F. Bogdan, Henry K. C. Woo, and C. H. Pan* 741

Effects of Gin Drying and Cleaning Practices on Properties of Bleached and Resin Treated Fabrics. *James N. Grant, Frederick R. Andrews, and Ruby H. Tsoi* 751

Panel Discussion on Cotton Quality Evaluation 758

LETTERS TO THE EDITOR

Radiation Polymerization of Acrylonitrile Onto Cotton. *Jett C. Arthur, Jr., Robert J. Demint, Wilbur F. McSherry, and Julian F. Jurgens* 759

An Investigation of Inorganic Salts and Oxides as Finishes for Cotton. *Ramon M. Esteve, Jr., Georgia Ellen Wright, and Pauline Beery Mack* 760

BOOK REVIEWS 761

REPRINT REQUESTS SHOULD BE DIRECTED TO THE AUTHORS

SEE ARTICLES FOR ADDRESSES

SEPTEMBER 1959
VOL. XXIX NO. 9

TEXTILE RESEARCH JOURNAL

Thermal Effects in Tire Cord Materials[1]

J. O. Wood, R. S. Goy, and F. S. Daruwalla

Dunlop Research Centre, Birmingham, England

Abstract

Consideration is given to the effect of heat on the strength and dimensional characteristics of typical tire textile materials. The dimensional change in a hot-stretched nylon cord is divided into two components: the change in filament length and the lateral packing of the filaments.

Dimensional changes are also related to the elastic behavior, to the shrinkage forces, and to the creep characteristics of the cord.

The generality of the thermal effects is demonstrated by data obtained using a range of textile fibers.

Introduction

Tire cord has to survive the effects of heat at four periods in its progress through tire manufacture and during its subsequent useful life on the road. First, the adhesive usually requires drying on the cord in a heated oven. If nylon is used this may be coupled with a hot stretching process involving temperatures in excess of 200° C. A measure of heating also occurs when the rubber is calendered onto the fabric sheet. Next comes the vulcanization process, in which the cord is subjected to temperatures of around 150° C. for a period of several minutes or possibly an hour or two depending on the type of tire under process. Finally, the tire may become hot while in use on the road.

More than one aspect of heat resistance therefore is required of the cord: it must not suffer permanent degradation from exposure to prolonged periods at elevated temperatures; it must resist as far as possible the reversible loss in strength which occurs with most textiles to a greater or lesser degree; and it must have maximum dimensional stability to minimize faults in the completed tire.

It is the dimensional effects which we propose to deal with here in greater detail. But first it is of interest to look at degradative and reversible losses in strength.

Heat Degradation

Permanent degradation appears very sensitive to conditions other than temperature; thus the presence or absence of oxygen has a marked effect on the degradation rate of nylon, and the relative merits of some textiles can be made to assume a different order depending on the applied conditions.

Waller, Bass, and Roseveare carried out tests under a variety of conditions and showed that *in*

[1] Presented at the Textile Research Institute Annual Meeting, New York City, March 23-24, 1959.

TABLE I

Days in oven at 125° C.	Percent loss in strength	
	Rayon	Nylon
7	22.6	13.0
28	47.0	49.0

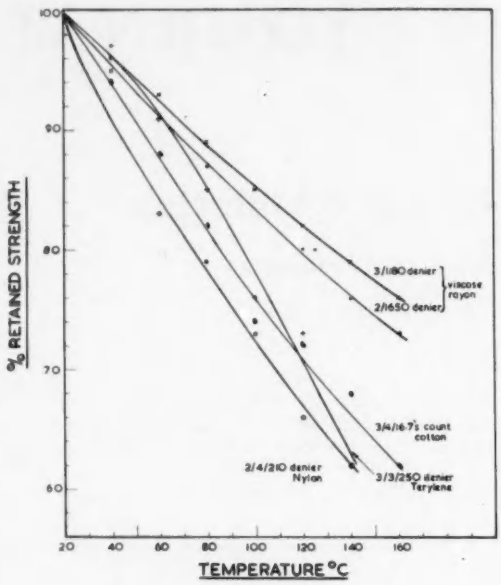

Fig. 1. Strength vs. temperature.

vacuo nylon lost much less strength than rayon; 8% as against 41% after 4 days at 150° C. [8]. The difference was much less marked when air and moisture were present. Our own experiments were made on test pieces of cord in vulcanized rubber; these were subjected to a period of heat treatment at the end of which the cords were extracted from the rubber and tested for strength. Comparison with cords which had undergone a similar vulcanization cycle but not the prolonged heat treatment provided the relative degradation data (Table I).

When this experiment was carried out under the particular conditions chosen there would seem to be little difference between the two materials. However, since then, additives have given increased heat resistance to certain textiles, and probably lower values of strength loss might be obtained under the same conditions.

Although heat degradation of the textile component is a potential source of danger to the tire, it does not

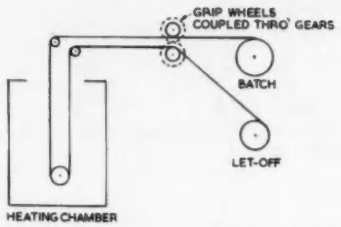

Fig. 2. Laboratory hot-stretching device.

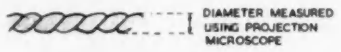

Fig. 3. Cord diameter.

yet seem to have entered as a major factor in determining tire life. It is, however, a factor which is probably assuming increased importance as tire running conditions become more severe.

Reversible Effects

The reversible loss in strength at elevated temperatures has been examined very thoroughly in this laboratory [4]. Similar studies were reported at the 1957 Annual Meeting of the Textile Research Institute when additional data were given for cords to which the adhesive had been applied [1]. The reversible component of the strength is that portion of the strength which is completely recovered when the temperature of the textile drops back to room conditions. For short periods, and provided the temperature is not excessive, no degradation occurs and only the reversible component operates. The effect may be summarized by expressing the data in terms of percentage retained strength. It is then seen that the more common tire textiles all behave in the same manner (Figure 1). However, the degree of sensitivity to temperature is not the same over the range considered; the thermoplastic cords and cotton form a lower group in which they lose a greater proportion of their strength with temperature and the viscose rayons form an upper group, losing a rather smaller proportion of their strength.

Dimensional Effects

Probably every possible material which may be considered as a tire cord is subject to some form of heat effect, if only thermal expansion. But this is of relatively insignificant magnitude when compared with the shrinkage and tension effects in most conventionally used tire textile materials. These effects may be conveniently demonstrated by making two

measurements—the free shrinkage at a specified temperature and the tension developed in the specimen when it is held at a constant length and heated.

These provide an index of the likely behavior of a tire cord during the vulcanization process when the cord is partially free to move through the hot, viscous rubber compound. The free shrinkage corresponds to an extreme case when there is complete freedom for the cord to slip around the bead wires during the vulcanization process; the force to hold to length on the other hand corresponds to the opposite extreme, where no movement occurs. It is evident that in practice the cord is in a state intermediate between the conditions exemplified by the two measured extremes.

At this stage in the process it is most desirable to maintain stability in the cord; excessive movement may lead to adhesion troubles and also deformity in the bead region. Further, the modulus will be reduced if shrinkage cannot be avoided, and this will lead to an increase in the growth characteristics of the cord. In effect the effort put into hot-stretching a nylon cord with the objective of reducing growth may be partially annulled by shrinkage in the cover.

It is proposed now to describe some experimental work in which a nylon cord is hot-stretched to varying extents, including negative extension, at a fixed temperature. The applied conditions will then be related to the dimensional changes which have occurred in the cord and also to the effect on the free shrinkage and the tension to hold to length.

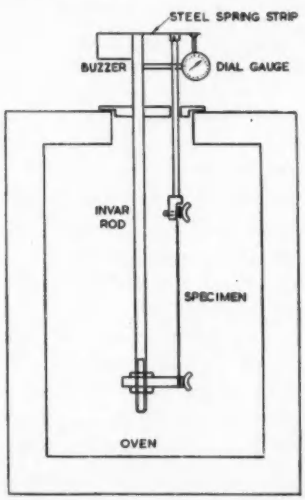

Fig. 4. Constant length tensometer.

Experimental

The experiments were performed on a 2/840-den. nylon cord made from British Nylon Spinners' type 600 yarn. The cord was in the raw state; no adhesive dip had been applied.

A simple single cord laboratory hot-stretching unit was used which applied a series of fixed extensions to the cord. At the same time the tension developed

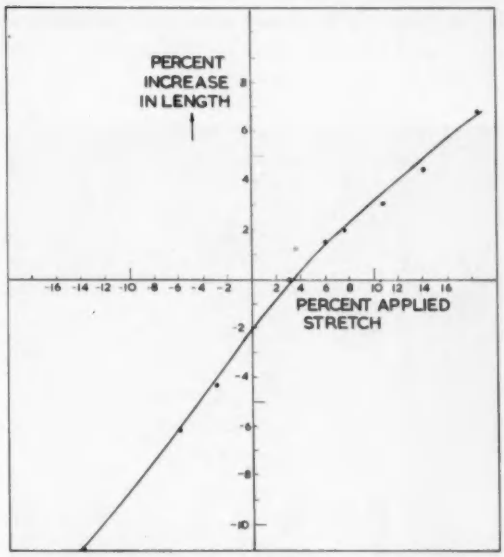

Fig. 5. Stretch applied vs. stretch retained.

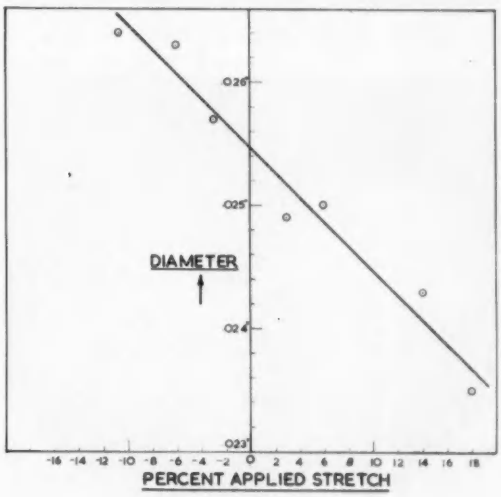

Fig. 6. Cord diameter vs. stretch applied.

in the cord was measured. A schematic drawing shows the method employed (Figure 2). The heating chamber was maintained at 220° C. for most of the operating period, though a smaller experiment was carried out at 210° C.

A fixed length of cord was run through at each prescribed condition; after treatment the length was measured again at room temperature and the percentage shrinkage or extension obtained. The cord diameter was also measured using a projection microscope, the figure recorded being the over-all diameter (Figure 3).

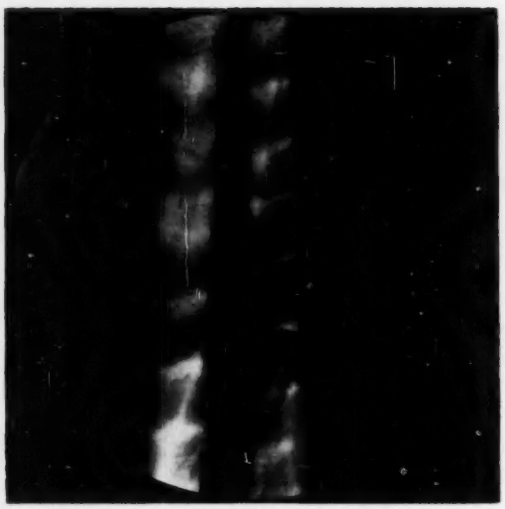

Fig. 7.

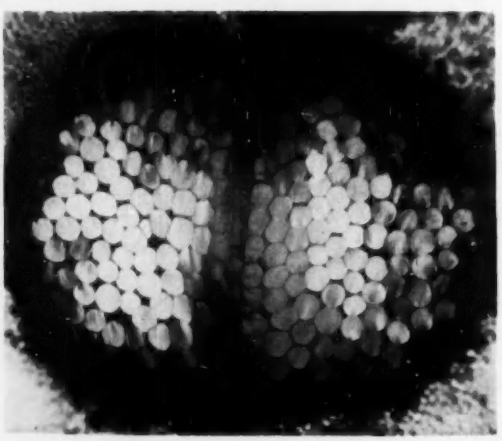

Fig. 8. Hot-stretched nylon.

Conventional load–elongation data were obtained using the Scott IP-4 inclined plane tensile tester.

The free shrinkage was measured by mounting a loop of cord on a bench under a weight of 100 g. The length was measured again under the same straightening load after the cord had been heated in an oven at 150° C. for 5 min. (A loop of cord is chosen to obviate errors due to loss of twist.)

A constant length tensometer was used to record the tension developed in the cord when heated to 150° C. The "backbone" of the device consists of an "Invar" nonexpanding alloy rod. To this is attached at the lower end a clamp and at the upper end the load recording device. The working mechanism can be seen in greater detail in the diagram (Figure 4). A buzzer is attached which overcomes contact friction in a crude but effective manner.

The tensometer is designed so that it can be dipped into an oven maintained at 150° C. The whole cord specimen is then brought up to 150° C. with consequent development of tension which is recorded on the dial gauge. It takes about 5 min. for the gauge to settle to a steady reading.

Measurements of the load–elongation characteristics, the free shrinkage, and the tension to hold to length were repeated on yarn extracted from the heat-treated cord.

The method of extraction used was as follows: the cord was gripped at both ends and one of the yarns was cut away leaving the second yarn still gripped; this second yarn thus retained the small amount of twist as it was when the yarn lay in the cord. A complete coverage of the range did not seem worth while because of the high level of crimp in certain

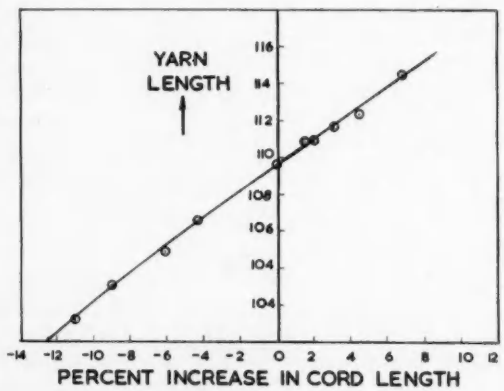

Fig. 9. Change in yarn length vs. change in cord length.

of the yarns; these were the ones to which a negative extension had been applied during the hot-stretching process.

Finally, to complete the study, growth tests were carried out at room temperature on the cords stretched by the various amounts. The equipment used has been described elsewhere [10].

Discussion

Dimensional Changes

The permanent change in the length of the nylon cord for the various degrees of applied stretch or allowed shrinkage is most easily appreciated by reference to the graph (Figure 5). It is apparent that only a portion of the applied stretch is imposed with any degree of permanence on the cord.

Coupled with the change in length is a diminution in the diameter of the cord (Figure 6). This arises from the inward pressure exerted by the two foldings on one another. Some indication of the magnitude of the force involved is provided by the calculation in Appendix I, where it is estimated that a tension of 5 lb. on the cord must result in a mean inward pressure of about 3000 lb./in^2.

At the center of the cord, in the region where the two yarns press together, the filaments in the opposed yarns cross one another so that the mean inward pressure is actually in the first place borne by a series of point contacts. Each one of these will correspond to the contact region where one cylindrical filament presses against an opposite filament running at an angle to the first. Obviously deformation must occur; the pressure in this contact region must greatly exceed the mean inward pressure calculated above. It is not surprising then that some evidence of deformation was obtained when filaments from a heat-treated cord were examined under the microscope [3]. Further independent evidence has since become available, confirming the effect [5]. A nylon filament viewed between crossed Nicols exhibited a group of striations (Figure 7). The spacing of the individual markings within the group could easily correspond to the spacing of the filaments lying side by side in the opposed folding. Another group of striations was found further along the filament at a distance which was of the correct order to correspond with the path-length of the filament from the center of the cord, round the outside, and back again to the center.

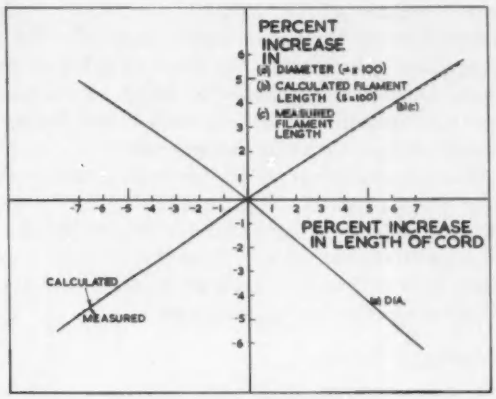

Fig. 10.

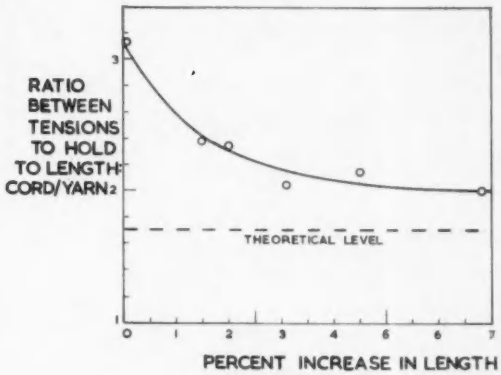

Fig. 11.

Another type of deformation—compression of the filaments into rods of partial hexagonal section—has also been observed (Figure 8).

The permanent extension of the filaments themselves in the cord was determined by simple computation from the two sets of data: the permanent extension of the cord as measured at room temperature and the length of yarn obtained from a prescribed length of cord during the measurement of twist (Figure 9).

It is clear now that the final properties of a hot-stretched cord result from a combination of two factors: the permanent extension imposed on the filaments and the permanent decrease in the diameter of the cord.

In Appendix II is shown a possible way of separating the two factors theoretically. From a knowledge of the permanent extension in the cord and the decrease in cord diameter it is possible to make a

second estimate of the change in the length of the filaments, using Equation 9 in Appendix II. Such an estimate is included in the graph, which also records the percentage change in length of the filaments, as computed by the first method, and the percentage change in diameter (Figure 10).

We may conclude from this that a cord having the same elastic properties as a hot-stretched cord could be made without further treatment beyond the doubling operation, but the yarn from which it was made would have to have a much higher modulus than that of the yarn in the hot-stretched cord.

Shrinkage Tensions

A further relationship which may be noted in passing is that between the tensions to hold to length in yarn and cord form. Equation 1 in Appendix I provides a basis for comparison, provided a factor of two is introduced to account for the combined action of both the yarns. The ratio expected between the two tensions for cord and yarn is approximately 1.7. In fact, a plot of this ratio starts at about 3.0 and drops towards the predicted value as cords of lower extensibility are considered (Figure 11). It is thought that this apparent discrepancy arises from the amount of crimp which remains in the yarn after it has been removed from the cord. In fact, as already mentioned in the description of the experiment, the crimp was so great in the yarns extracted from shrunk cords that further tension measurements became meaningless.

On the cord itself it is seen that the tension to hold to length and the free shrinkage at 150° C. both increase with increasing applied stretch. This is in accord with expectation (Figures 12 and 13).

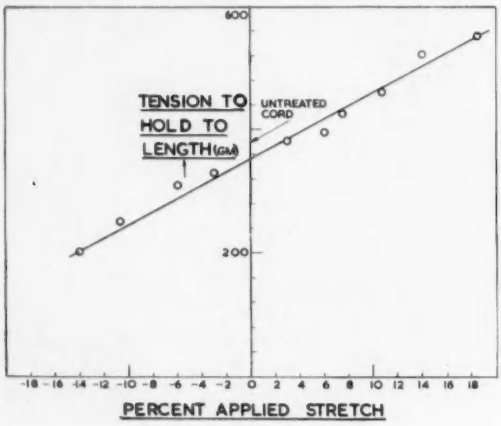

Fig. 12.

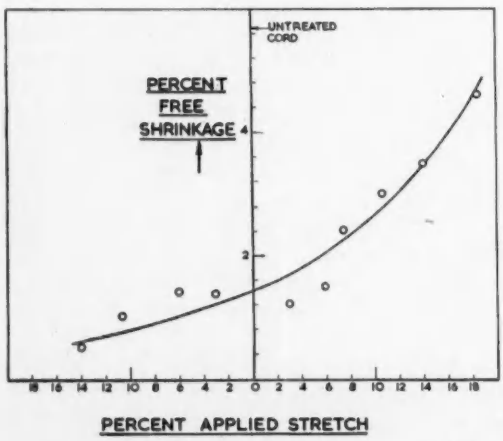

Fig. 13. (Values to the left of zero are negative.)

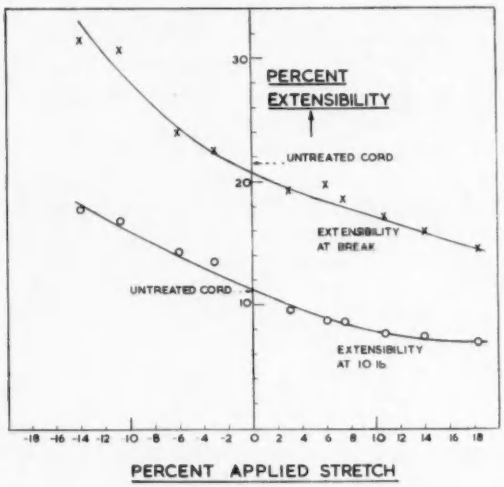

Fig. 14.

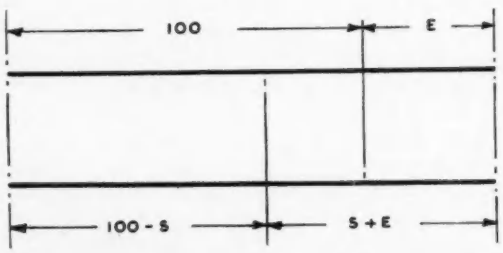

Fig. 15. Model of cord behavior. Top, before shrinkage; bottom, after.

Elastic Behavior

It is seen that the extensibility at 10 lb. is reduced in the way expected, and the extension at break follows a similar pattern (Figure 14).

It is of interest now to see whether a relationship can be found between the extension characteristics of the cord and the permanent change in length which has been brought about by the hot-processing.

The simplest model which can be postulated assumes that a cord will always break at the same final extension based on its original length before stretching or shrinking [2] (Figure 15). Thus a cord 100 in. long having an extension at break of $E\%$ becomes after shrinkage by an amount S a cord of length $100 - S$, which extends by $S + E$ before it breaks. Expressed as a percentage breaking extension this becomes

$$\frac{S + E}{100 - S} \times 100$$

Before attempting to treat the nylon cord according to the present model behavior we may record the quite surprising agreement between such a simple model and the behavior of a Terylene cord which was allowed to shrink freely at various temperatures (Figure 16). Except for the final point there would seem to be complete agreement within experimental error between the calculated extensibility and the actual recorded value. This cord had not suffered degradation during the process, whereas quite a large loss in strength had occurred when the nylon cord was shrunk. This is reflected in the calculated figures for the extension at break, where degradation is associated with a considerable departure from the predicted values. However, equivalent extensibility data were obtained on the same type of cord by dropping the temperature from 220 to 210° C. and appropriately adjusting the applied extension. It is then seen that there is a return to agreement between actual and predicted values over the range where disagreement had previously been found (Figure 17).

Growth

The original objective of the hot-stretching process was the production of a low extensibility cord; hence reduction in cord growth. A laboratory assessment of the effectiveness of the hot-stretching process in reducing growth is provided by the curves of total growth against applied stretch (Figure 18). Broadly, the growth is reduced by increasing the applied degree of stretch.

However, it is difficult to relate these data directly to tire performance because of the intervening processes which follow hot-stretching. Shrinkage can occur during vulcanization, and this means that the growth characteristics may deteriorate to some extent. Knowledge of the free shrinkage and tension

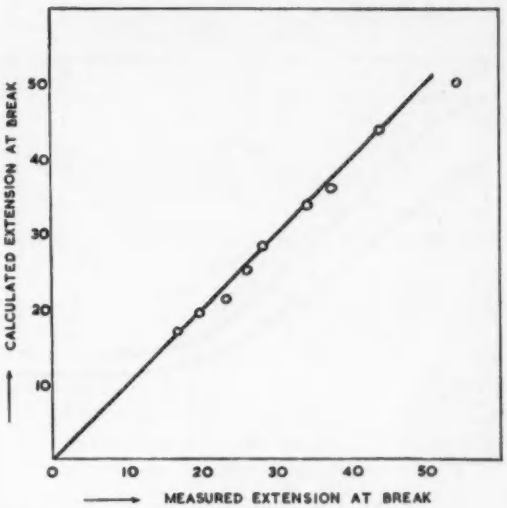

Fig. 16. Extensibility at break of shrunk Terylene cord 3/3/200 den.

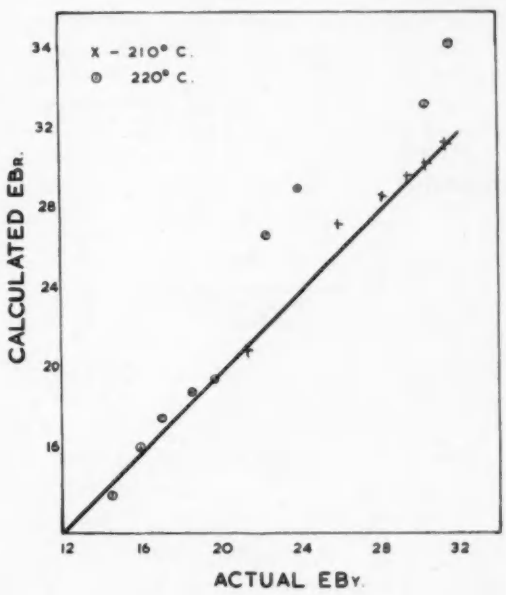

Fig. 17.

to hold to length characteristics is useful in this context; a cord that is highly set, i.e., has a low free shrinkage, and a low force to hold to length should be affected less by the heating experienced during vulcanization and it should therefore retain lower growth characteristics than a cord which is less well set.

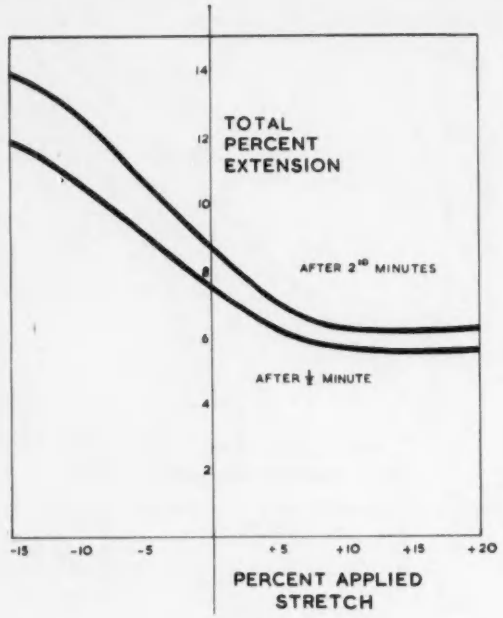

Fig. 18.

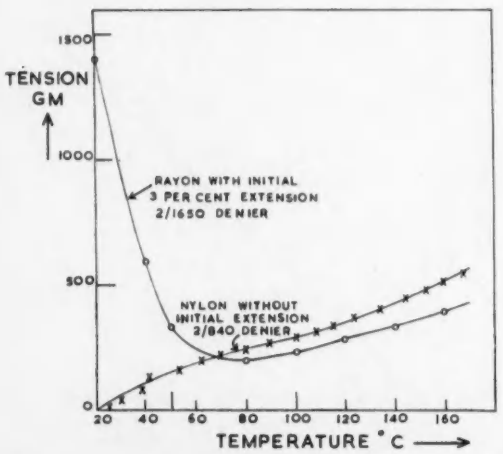

Fig. 19. Tension–temperature relations for rayon and nylon tire cords.

Tension Effects in Other Materials

A well set nylon cord should also be less of a potential troublemaker during the vulcanization process. The fact that nylon calls for special treatment raises the query as to why rayon should be relatively easy to process. With this in mind a rayon cord was put through an approximate temperature cycle corresponding to that to which it would be subjected during tire vulcanization. Some extension occurs when the cover is shaped and so a 3% extension was applied to the cord initially. The tension–temperature relation was obtained using the constant length tensometer (Figure 19). An equivalent curve is also given for nylon but starting from zero initial extension. In contrast to nylon it is seen that the tension in the rayon cord drops rapidly at first until a minimum is reached; thereafter a gradual increase in tension is observed. To study if the drop in tension was caused primarily by the expulsion of moisture, the experiment was extended to include an initial drying period over phosphorus pentoxide. During this period there was a large fall-off in tension. Subsequently an approximate straight line relation was obtained between tension and temperature (Figure 20).

It would appear from this that a certain amount of thermal shrinkage occurs in rayon, but the effect

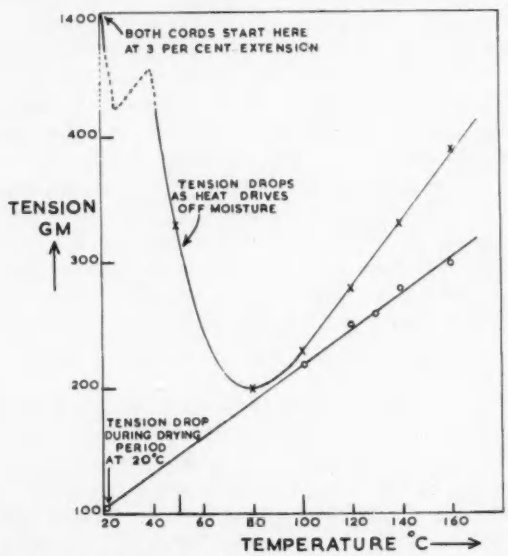

Fig. 20. Tension–temperature relations for rayon cord showing the interaction of moisture.

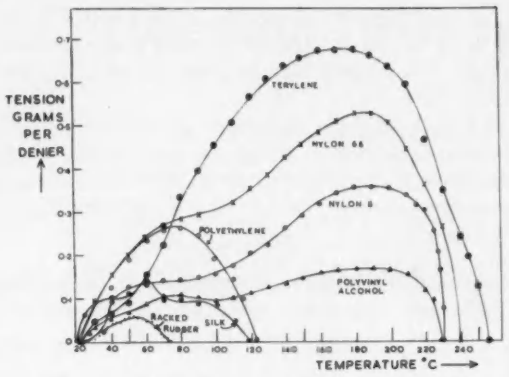

Fig. 21. Tension to hold to length vs. temperature for several materials.

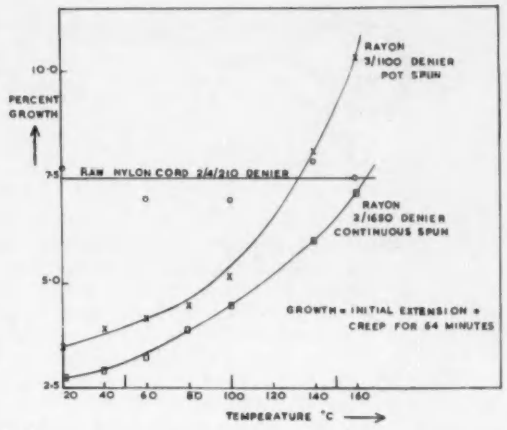
PERCENT GROWTH
RAYON 3/1100 DENIER POT SPUN
RAW NYLON CORD 2/4/210 DENIER
RAYON 3/1650 DENIER CONTINUOUS SPUN
GROWTH = INITIAL EXTENSION + CREEP FOR 64 MINUTES
TEMPERATURE °C

Fig. 22. Comparative growth of rayon and nylon over a temperature range.

is not usually observed because of rayon's high moisture sensitivity.

An indication of the generality of such tension–temperature effects is provided by the series of curves relating to a variety of different materials (Figure 21).

The effect of temperature on growth is important to the tire manufacturer, more particularly as tire running temperatures still continue to rise. With rising temperature it seems that the shrinkage effect in nylon plays a large part in holding the cord back from increased extension. In fact, in the particular experiment reported here, the growth hardly altered over the temperature range studied (Figure 22). It should be added that the nylon cords were held to length until the specified temperature was reached; then the load was applied and growth data obtained. The rayon cords, on the other hand, do not seem to possess sufficiently strong thermal shrinkage characteristics to resist growth at elevated temperatures, and the curve of growth against temperature is an increasing one over the whole range.

Conclusion

It is rather regrettable to record that an account of thermal effects in tire cords amounts almost entirely to a list of defects—looked at from the tire manufacturer's point of view, of course. At elevated temperatures strength may be lost permanently, or at best it is lost temporarily just so long as the higher temperature is maintained. Then the thermoplastic fibers exhibit shrinkage tendencies which make them quite awkward to process. Rayon does not perhaps lose quite so much strength with rising temperature, but its growth characteristics become very poor above about 100° C.

All the conventional fibers appear to be similarly afflicted. Only glass fiber can be picked out as having exceptional properties under hot conditions, unless one is permitted to regard steel as a textile. Certainly it has to be treated somewhat similarly when used in tires. Possibly certain of the properties of steel may be regarded as target qualities when a search is made for the ideal industrial textile. It has the high modulus so frequently sought and its dimensional stability under all conditions is beyond reproach. In some applications perhaps it is too rigid and there may well be a place for a textile having properties lying in a range between present-day textiles and steel. It will be interesting to see whether such a textile will be developed in the future, and whether it will then be able to justify itself in the field of industrial applications.

Acknowledgments

The authors are indebted to Mr. W. L. Jackson for the design of the "tension to hold to length" device, to Mr. J. A. Jenkins for creep data on the hot-stretched nylon cords, to Herr Kallinich for Figure 8, and to their colleagues for helpful discussions. Thanks are also due to the Directors of the Dunlop Rubber Company for permission to disclose the information given in the paper.

Appendix I: Force Between Foldings

The study of cord geometry in the general case leads to a rather complex set of formulas which de-

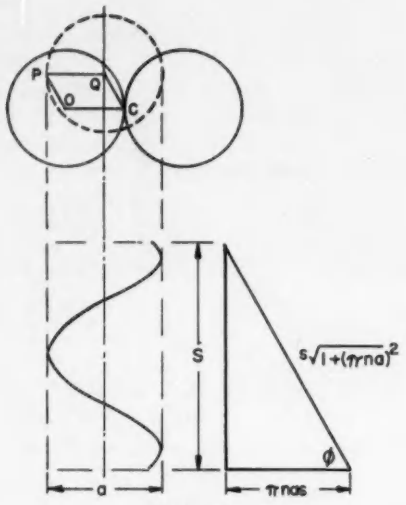

Fig. 23.

scribe in mathematical terms the path of any filament in the corded structure [6, 7]. However, a much simpler model may be employed for a two-fold corded structure if it is assumed that the twists in the yarn and the cord are equal and opposite [9]. When such is the case any filament passing through the point P in the cross section of the cord describes a helical path along the cord centered on the point Q where $OCQP$ is a rhombus (Figure 23). Tension in the filament will result in an inward pressure directed along the line PQ parallel to the line joining the centers of the two opposed yarns. Evidently the forces exerted by any filament in the yarn centered on the point O will be similarly directed.

The radius of curvature of the helix is $a \sec^2 \phi$; hence the inward force p due to a tension f in the filament will be $\frac{f}{a} \cos^2 \phi$.

The component force in the filament contributing to the total tension parallel to the cord axis is given by

$$t = f \sin \phi \tag{1}$$

Thus t and p assume the relationship

$$p = t/a \cos \phi \cot \phi \tag{2}$$

The total inward force P may then be expressed in terms of the tension T in the cord. Thus

$$P = \frac{T}{2a} \cos \phi \cot \phi \tag{3}$$

$$= \frac{T}{2a} \frac{(\pi na)^2}{1 + (\pi na)^2} \tag{4}$$

If the typical values $T = 5$ lb., $a = 0.0128$ in., $n = 12$ turns/in. $[(\pi na)^2 = 0.232]$ are inserted, then $P = (5 \times 0.232)/(2 \times 0.0128 \times 1.11) = 41$ lb./in.

Or if we assume the width of the contact area between foldings to be of the same order as the diameter of one of the yarns (0.0128 in.), the mean pressure between the foldings = 41/0.0128 p.s.i. ~3000 p.s.i.

Appendix II: Relation Between Cord Elongation, Filament Elongation, and Radial Compression

Consider once again the model used in Appendix I. We see by inspection of the figure that the filament length l is given by

$$l^2 = s^2[1 + (\pi na)^2] \tag{5}$$

In addition, the turns of twist between two fixed points on the cord remain constant regardless of any extension applied, i.e.,

$$ns = \text{const.} \tag{6}$$

Logarithmic differentiation and combination of these relations yields the expression

$$\frac{\Delta l}{l} = \frac{\Delta s}{s} + \frac{(\pi na)^2}{1 + (\pi na)^2}\left[\frac{\Delta a}{a} - \frac{\Delta s}{s}\right] \tag{7}$$

Alternatively this may be written

$$\gamma = \epsilon + \frac{(\pi na)^2}{1 + (\pi na)^2}[\alpha - \epsilon] \tag{8}$$

where γ = filament strain, ϵ = cord strain, and α = radial strain.

For the value of a taken to be 0.0128 in., Equation 8 reduces to

$$\gamma = 0.812\epsilon + 0.188\alpha \tag{9}$$

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Polyolefin Fibers and Polymer Structure[1]

Victor L. Erlich

Reeves Brothers, Inc., New York 18, N. Y.

Abstract

The polyolefins (or, more restrictedly, the poly-alpha-olefins) are a growing family of polymers which comprise the straight linear polyethylene or polymethylene and its derivatives. Their fiber-forming properties are based on the paraffinic backbone common to all these polymers; the derivatives can have an infinite variety of structures, and this has an extremely pronounced influence upon the fiber properties. Present polymerization chemistry and technique permit close control of these structures to a high degree of purity and in turn the control of the fibers processed therefrom.

Length and distribution of the molecular chains, their stereospecific configurations, and crystallinity and its degree are shown in their effect on the polyethylenes (low to high density) and on polypropylene, and future developments are foreseen.

The case of the polyolefin fibers is not that of "one more" synthetic fiber; the polyolefins may well become the classical, even textbook example of the intricate relationship between molecular structure and fiber properties.

As a new textile material the polypropylene fiber is of particular interest economically and in its characteristics—all the more so as problems such as ultraviolet stability and dyeability are being overcome.

THE TERM "polyolefins" is now used commonly to designate a group of synthetic resins which under the name of polyethylene and more recently of polypropylene have become a greatly publicized part of the chemical manufacturing and the plastic processing industry. It is no secret that production capacities allotted to this new field have at present outrun the volume of consumer acceptance, but it is reasonable to believe that a healthy balance will result within a few years.

To find such balance requires not only the growth of existing markets but the development of new applications. It is not sufficient to count on the comparatively low price of these resins; suitability of the properties for the end uses is the determining factor. This explains the interest which exploded with the appearance of the new linear polyethylene, followed soon by polypropylene, because a wide array of properties became available for the same family of resins. This is particularly pronounced when these resins are processed to fibers. From the standpoint of the resin manufacturer, the volume of application in the textile field remains to date a deceptively small slice in their total end use patterns; in spite of this, the hope of potential growth exists, and some aspects of the background upon which such expectations are founded will be discussed here.

[1] Paper presented before the Annual Meeting of Textile Research Institute, March 24, 1959.

What are Polyolefins?

Figure 1 presents a list of some of the chemical compounds called olefins from which the polyolefins are produced. More restrictedly these are alpha-olefins, because the double bond is located between the two first carbon atoms of the compounds having three or more carbon atoms and which can be considered as substituted ethylenes. The resulting poly-alpha-olefins have therefore in common the straight line of carbon atoms as a paraffinic chain.

Polyethylene, the simplest representative, could also be called polymethylene; the higher poly-alpha-olefins have on every second carbon one hydrogen substituted by a side chain or branch, and the paraffinic chain forms the backbone of the molecular structure.

This is textbook theory. Under industrial conditions, the first polyethylene, which remained the "conventional" one for about twenty years, was everything but polymethylene. It had a great variety of branches in different lengths attached at random to the main chains; it also contained some reactive

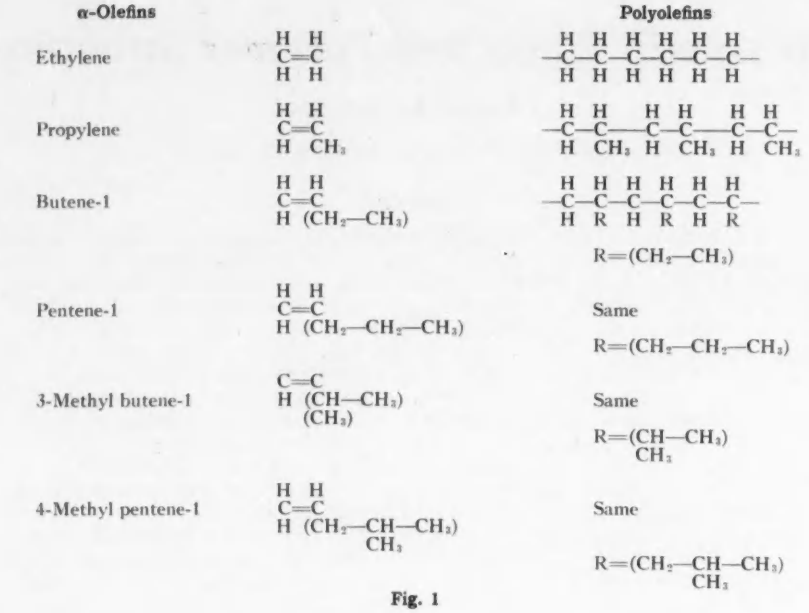

Fig. 1

double bonds, and therefore was a conglomerate of various ill-defined polyolefins with widely different lengths of the paraffinic chain.

Controlled Polymerization

It is one of the great achievements of modern polymerization chemistry and technique that the reaction can now be controlled very closely to the desired molecular structure. The nearest approach to the polymethylene chain was the "linear" polyethylene first brought on the market by Phillips Petroleum Company with less than 2.5 side chains per 1000 carbons. Before this, the so-called Ziegler type, which has about 3 to 4 such branches, had already become available, and "modified" linear polyethylenes are now produced which contain, for instance, a limited number of methyl- and butyl- side groups. The impact of the varying molecular structure on the physical properties was a surprisingly great one, and became the stimulating factor in the industrial development of the so-called polyethylenes.

Polypropylene, its first cousin, was barely considered as a potential plastic and even less a textile material until Professor Gulio Natta of Milan brought a new revolutionary understanding of this type of polymerization, and this permitted the control of the reaction to a degree unsuspected before. (The composition of specific metal-organic catalysts and the operating temperature are the controlling factors whereby low temperatures and low pressures are prevalent.)

Stereospecific Molecular Structures

This new concept became of dramatic importance for the substituted ethylene polymers described above. The side chains are branching out from the linear backbone into the molecular space, making the molecular structure a steric one. It is evident that such branching can go into different directions, thus building different steric configurations which now can be specifically controlled to make them "stereospecific" [3, 4, 5].

Figure 2 is an illustration given by Natta. He terms "isotactic" when all the branches are located in the same direction on one side of the linear chain, "syndiotactic" when they alternate regularly to both sides, and "atactic" for the nonspecific random distribution. The "isotactic" form is the one of great practical importance. This is not confined to polypropylene; other poly-alpha-olefins have been prepared in this configuration. It also has its impact on other polymers, to mention especially those of

TABLE I. Comparison of Structure and Melting Ranges

Polymer	Specific gravity range	Melting range °C.	Melting range °F.
Polyethylene branched types	0.91–0.93	107–121	225–250
Polyethylene linear types	0.95–0.97	130–138	265–280
Polypropylene isotactic	0.87–0.94	165–176*,†	330–349
Polybutene-1 isotactic	0.91	125–128†,‡	257–262
Polypentene-1 isotactic	0.87	75–80‡	167–176
Poly-3-methyl butene-1 isotactic	0.90	245 ,300‡,**	470 ,570
Poly-4-methyl pentene-1 isotactic	0.83	235 ,241**,††	455 ,466
Poly-styrene atactic (conventional)	1.04–1.05	99–110	210–230
Poly-styrene isotactic	1.10	240‡‡	464
Poly-*o*-methyl styrene atactic	—	180–185***	356–365
Poly-*o*-methyl styrene isotactic	—	above 360‡‡	680

* [4].
† [5].
‡ [3].
** W. George, Celanese Corporation of America.
†† Natta; unpublished data.
‡‡ [6].
*** American Cyanamid Corporation (CYMAC 400).

styrene, of diolefins such as butadiene, isoprene in the elastomer field, and even of nonhydrocarbon monomers [6]. The new polymerization technique also permits producing orderly arranged polymers, which have for instance two different side groups alternatively attached to the paraffinic chain.

The mechanical properties of similar polymers differ widely with their steric configurations. This influence involves even similar isotactic polymers if their different side chains vary in their relative steric positions, as shown recently by Natta for optically active isomers [6].

Most striking is the fact that the isotactic polymers have much higher melting points and greater stiffness due to crystallinity. These are some of the reasons why isotactic polypropylene aroused such interest. Its melting point can reach 176° C. (349° F.)

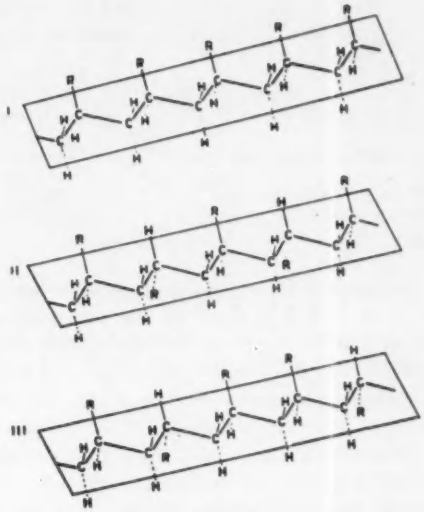

Fig. 2. Steric configurations of polyolefins. R, side chain; I, isotactic; II, syndiotactic; III, atactic.

whereas its atactic form is a soft, elastomeric material which is not fiber-forming; the isotactic polypropylene can be processed to a high-tenacity textile fiber.

Table I illustrates this for the isotactic polyolefins listed in Figure 1 as well as for polystyrene and poly-*o*-methyl styrene. These isotactic polymers can be produced in a "steric purity" which can exceed 95%.

Molecular Weight and Melt-Index

Such regularity of these new polymers also includes the chain lengths; this means the molecular weight. In the older polymerization methods which did not use specific catalysts (at low temperatures and low pressure), wide variations resulted not only in the configuration but even more so in the lengths of the individual molecular chains; quite short and very long chains were distributed at random. Substantial variations occurred from lot to lot of the produced polymer and its processed end-products (fibers, for instance), and this shows the importance of "molecular weight distribution."

All measurements of the physical properties gave average values which were not truly representative of the polymer. The average molecular weights of the polymers are correlated with their viscosities in a solution or in the molten state. The measurement of the solution (intrinsic) viscosity is the more reliable and accurate one, but the melt-viscosity is

TABLE II. Average Molecular Weights of Polyolefins
Practical Ranges for Production of Filaments

Polymer	Molecular weight range	Monomer-units per molecule	Carbon atoms in the paraffinic chain	Tenacities of oriented fils (g./den.)
Polyethylene branched types	19,000– 25,000	650–900	Variable, 1,000– 1,500	1–2½
Polyethylene linear types	60,000–130,000	2,100– 4,600	4,000– 9,000	5–9
Polypropylene isotactic	300,000–450,000	7,000–10,000	14,000–20,000	5–10

often convenient for thermoplastic resins because it gives some indication also for the processibility in extrusion. This is the "melt-index" often referred to, although it gives useful comparative indications only within a range of polymers of the same structural type. It serves as a guide for the manufacturer and the processor for the range of (average) molecular weights within which end-products of desired properties can be expected.

Table II gives a tabulation for such ranges as they are at present preferred for the production of polyolefin filaments, along with their relation to the tenacities of the respective oriented filaments. For linear polyethylene the higher index of 0.7 represents the lower practical limit of viscosity and molecular weight, whereas 0.2 represents an upper limit beyond which the melt-viscosity becomes too high to permit practical extrusion conditions. On the other hand, the melt-index of isotactic polypropylene, when measured at the same temperature (of 198° C. or 388° F.), would be markedly higher, in spite of its much greater molecular weight, because the melt viscosity is lower in spite of the higher melting point.

TABLE III. Correlations of Crystallinity and Density for Polyethylenes and Polypropylene
(Room temperature)

Polymer	Density, g./cc.	Crystallinity degree, %	Stiffness modulus, lb./sq. in.
Polyethylenes			
Branched			
Amorph	(0.84)	0	0
Low density	0.92	60/65	25/30,000
Medium density	0.935	75	60/65,000
Linear			
Phillips copolymer	0.945	81	83,000
Ziegler type	0.95	85	90/110,000
Phillips type	0.96	91	130/150,000
	(1.00)	(100)	
Polypropylene			
Isotactic			
Amorph (molten)	(0.85)	0	0
Medium	0.90	60/65	125/130,000
(Commercial as used for fibers)	0.91	70/75	130/180,000
High crystalline	0.92	80/85	200/220,000
	(0.93/0.94)	(100)	

Crystallinity

The choice of the basic monomer-units and the conditions of polymerization are controlling factors for the mechanical properties of the resulting polymers, and consequently to a large degree also for the characteristics of the fibers processed therefrom. The length and configuration of the molecular structures are existent already in the liquid state from which the fibers are produced by melt-extrusion. The extruded filaments after being solidified by cooling have to be further processed because the molecular chains in the melt are quite randomly distributed and not aligned along the fiber axis. They have to be "oriented" in this direction to give the fiber the chance of making best use of the characteristics of the molecular structures. These aligned molecules must be prevented from sliding or slipping along each other. Attractive forces are active between these molecular chains and are most effective due to the fact that crystallites are present in the oriented fiber. These crystallites are embedded between amorphous regions. The size of these crystallites and the degree of crystallinity are determining factors for the strength and stiffness or flexibility of the fiber, whereas the extent and location of the amorphous regions influence their resilience.

The tendency to form crystallites depends on the structure of the polymer. For instance, linear polyethylene shows much greater crystallinity than the branched type; the same is true for the isotactic polymers compared with the irregular atactic ones, and in both cases for higher molecular weight polymers. But the degree of such crystallinity in the final fiber is also a result of its history during proc-

essing (the conditions of cooling the extruded filaments and their orientation by drawing and subsequent annealing). Rapid quenching of the molten filament to low temperatures inhibits crystallization; the higher the orientation the greater will be the degree of crystallinity. Temperature and time of annealing are influential, and aging phenomena also are observed to increase crystallinity.

Higher crystallinity means denser packing of the molecules, and this in turn finds its expression in the density of the polymer.

Table III gives a tabulation of these correlations for the polyethylenes and for isotactic polypropylene as compiled from data established by Natta and also by Phillips Chemical, Celanese Corp., and Esso Research. The correlations were found to be linear at room temperature for polymers of the same structure such as straight linear polyethylene [9] and isotactic polypropylene [7, 8]. The table also shows that the stiffness increased in each group of polymers with the degree of crystallinity, which also raises the tensile strength of the oriented fibers but reduces their elongation to break at room temperature. With rising temperature, the crystallinity, although decreasing in degree, remains more or less intact up to a "transition point" where the crystals become disorderly and finally disappear into amorphous material. This is practically the "softening" point at which the fiber loses its rigidity and its strength, and which, for the polyolefin fibers, is close to the melting range; it depends on the polymer structure and on the pressure to which the material may be exposed.

Finally, it should be mentioned that the melting point is raised somewhat with increasing crystallinity, but this influence is by far not as pronounced as that of the degree of isotacticity.

Properties of Polyolefin Filaments

This basic discussion of the polyolefin resins appeared necessary to explain how intricate the relations are between the nature and structure of these polymers and the properties of the respective fibers. The result is a broad pattern of fiber characteristics and gives in turn the means of adjusting the properties to desired end uses. The number of resin types will continue to increase to make available new polymers and specific copolymers not only of various alpha-olefins but also of their combinations with other chemical groups. Therefore we have the prospect of an endless variety from which to choose for

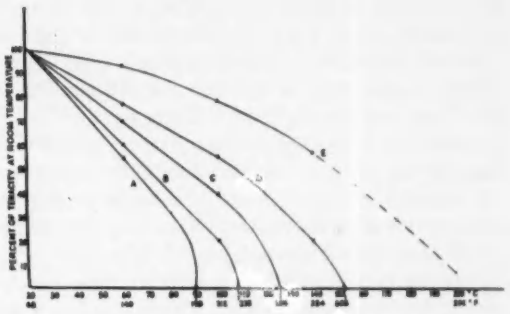

Fig. 3. Strength-temperature relation of polyolefin fibers. A, branched polyethylene (low molecular weight); B, branched polyethylene (medium molecular weight); C, linear polyethylene; D, isotactic polypropylene; E, nylon 66.

the production of tailor-made fibers. But for the moment, the fibers made commercially are still polyolefins based exclusively on ethylene, propylene, and (for some copolymers) also on butyl-groups. They are therefore all paraffinic in nature with the respective chemical properties varying somewhat in degree [2].

Table IV gives a listing of some of the physical properties of continuous filaments. Oriented polypropylene fibers and those of linear polyethylene have about the same strengths at room temperature, but there are some pronounced advantages for textile applications in favor of the new fiber.

Figure 3 gives curves [2] on the strength–temperature relation for polyethylene (low and high density), polypropylene, and nylon 6/6, with the tenacities calculated in percent of the respective values at room temperature [1]. This is meant to demonstrate that higher softening points of the polymer are of interest not only because of the wider temperature range but also because fibers having greater strength at intermediate points are obtained. For instance, tenacity of polypropylene at 212° F. may be about 40% higher and at 240° F. about double that of linear polyethylene.

Of considerable (perhaps decisive) importance is the outstanding resilience and memory of the polypropylene fiber, whereas linear polyethylene performs quite poorly in this respect ([1], Figure V).

Oriented filaments of straight linear polyethylene of highest density (0.96) and highest crystallinity cannot be exposed to a dead load of more than about

[2] Reproduced with authorization of the editors of *Modern Textiles Magazine.*

20% of their breaking strength without showing a pronounced "cold flow" or "creep" which leads to continuing elongation and subsequent break. Under a load of, say, 40% such linear polyethylene "runs away" in a matter of hours. Ziegler type polymers (density 0.95) and copolymers of the Phillips type designed for the purpose perform much better, but still cannot compare with isotactic polypropylene fibers, which show only a very slow creep even under a 40% load ([1], Figures VI and VII).

Isotactic polypropylene was said to show brittleness at low temperature on a higher level than for polyethylene, which does not deteriorate at −100° C. (−150° F.). Brittleness temperatures given for polypropylene vary from +15° C. (+59° F.) for unoriented polymer to much lower temperatures for oriented material. For instance, tests made on filaments proved workability to be good at −20° C. (−4° F.), and others made on oriented films proved this temperature to be at least as low as −70° C. (−94° F.). Apparently the better the orientation the lower the brittleness point. Another difficulty was a tendency of some fibers to fibrillate or to split along the axis; this would affect the resistance to abrasion, which in itself is comparable or better than that of linear polyethylene. This problem is partly a matter of molecular structure and crystallinity. In both instances well adjusted conditions in the processing to fibers also are influential because they control the positions of the molecular chains in the filaments and, in a measure, the degree of crystallinity.

Another point is the processibility of the polymer to fibers. In melt-extrusion the heat-stability of the polymer was a matter of concern at the practical extrusion temperatures of 220–290° C. (430–550° F.) which are much higher than the melting point. This matter is now under control because the resin producers are adding adequate stabilizers to counteract deteriorating oxidation, at least during the short periods of exposure in the extrusion equipment.

It is necessary to stabilize these fibers against degradation under sunlight, a difficulty common to many other fibers, natural and synthetic. It had been a severe drawback in the early days of polyethylene, more for the branched types than for the linear ones.

The study of oxygen uptake by the different polymers had to be a first point of attack; attention is drawn to the basic work done at Bell Telephone Laboratories [10]. In other laboratories literally hundreds of antioxidants have been tested and many found effective for thermal stabilization but only

TABLE IV. Comparison of Physical Properties of Commercial Polyolefin Filaments

Polymer		Spec. gravity	Tenacity, g./den.	Elongation to rupture, %	Shrinkage, % of orig. length (at 212° F.)	Softening range (without load), ° F.
Polyethylenes	Reevon desig.					
Branched low mol. weight (19–20,000)	400	0.92	1.0/1.5	45/50	50/60	185/205
Branched med. mol. weight (23–25,000)	600	0.92	2.0/2.3	25/30	40/50	220/230
Modif. branched	670	0.93	3.0/3.3	17/25	25/35	245/250
Modif. linear	760	0.945	5.0/5.5	14/20	10/15	250/255
Straight linear	700	0.95	5.5/7.0	10/20	5/10	255/265
		0.96	6.5/8.0	10/20	5/10	260/270
Polypropylene Isotactic	800	0.90/0.91	5.5/7.0	15/25	10/15	300/310
Nylon 6/6						
Regular dry		1.14	4.5/6.0	25/30	5/10	(470/480)
Regular wet			4.0/5.2			
High ten. dry		1.14	6/9	15/28	5/10	(470/480)
High ten. wet			5.5/7.5			
Polyvinylidene chloride		1.65	1.8/2.2	20/30	10/15	240/280

very few for ultraviolet [11, 12]. In Reeves' laboratories methods have been developed based on synergistic action of antioxidants, ultraviolet absorbents, pigments, and their adequate compounding with the polymer. They provide protection of monofilaments in a wide range of colors to a degree satisfactory for commercial outdoor applications.

Figure 4 shows the effect of ultraviolet irradiation in accelerated laboratory tests as measured by the loss in breaking strength of round polyethylene filaments; in each test-run stabilized filaments were compared with unstabilized specimens under the same conditions. Strict correlation between such laboratory experiments and actual outdoor exposure cannot be expected, but a multitude of polyethylene fabrics exposed outdoors in South Florida had, after one year, quite closely the same degree of loss in strength as did similar fabrics in 1000 hours in the laboratory.[3]

With polypropylene, particularly in fiber form, this difficulty again became very pronounced, but considerable progress has been achieved by Hercules Powder on their Profax resin and by Reeves on a wide color range of pigmented filaments.

Figure 5 gives the results on polypropylene monofilaments. As yet they are not quite up to the high stability of the special polyethylene but warrant a practically satisfactory performance.

Will Polyolefins Enter the Textile Field Proper?

Up to this day commercial production of polyolefin fibers, polyethylene as well as polypropylene, remains confined to that of monofilaments as such or in the form of multifilaments in gauges ranging from 2,000 down to say 40 den., but preponderantly between 1,000 and 300. Such relatively heavy gauges are used for industrial purposes, fabrics, ropes, etc. Open markets may absorb limited millions of pounds per year.

But industrial projects now extend beyond such limitation. Professor Natta announced that Montecatini is building in Italy a plant with an initial capacity of 10 millions pounds per year of staple fiber and continuous filament yarn, and similar projects exist in this country.

Filament yarns of low textile deniers can be and have been made from linear polyethylene also, but the combination of high strength and excellent resilience as well as better processibility is much more encouraging for polypropylene. These fibers lend themselves to desirable textile operations; they can be spun, crimped, textured, used for knitting, and for woven and nonwoven fabrics, either alone or, most promisingly, in blends with natural or other synthetic fibers. A great variety of samples of such fabrics has been shown to prove the point.

Nevertheless, we must remain aware of the limitations, as discussed here, and the competitive position with other established synthetic fibers. In this respect, economic considerations are striking but not all-decisive assets in favor of polypropylene. And, while plants are in construction, experimental work continues.

One of the developments of prime importance will be dyeing of these fibers, which at present are colored by pigmentation. Copolymers with dyeable and less hydrophobic side chains will be forthcoming sooner or later. For straight polypropylene fibers, the newer techniques used for some of the other synthetics are helpful guides. Quite encouraging progress has been made in an array of colors, but the choice is still limited for the time being.

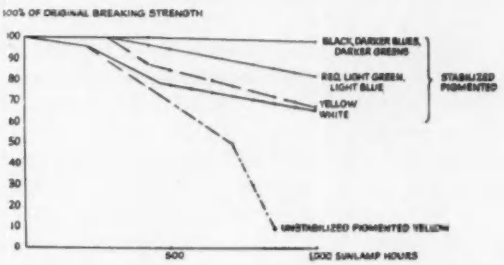

Fig. 4. Accelerated weathering tests on high density polyethylene monofilaments (round 0.012 in.).

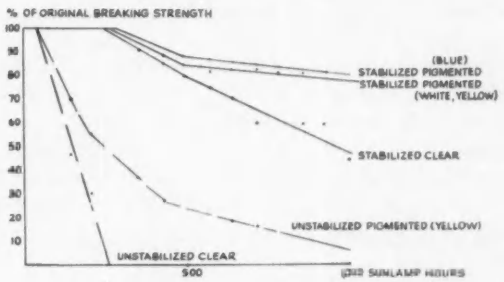

Fig. 5. Accelerated weathering tests on polypropylene monofilaments (round 0.012 in.).

[3] This was not observed on Saran fabrics which performed outdoors better than under laboratory conditions, probably due to tendency to darken under actual sunlight.

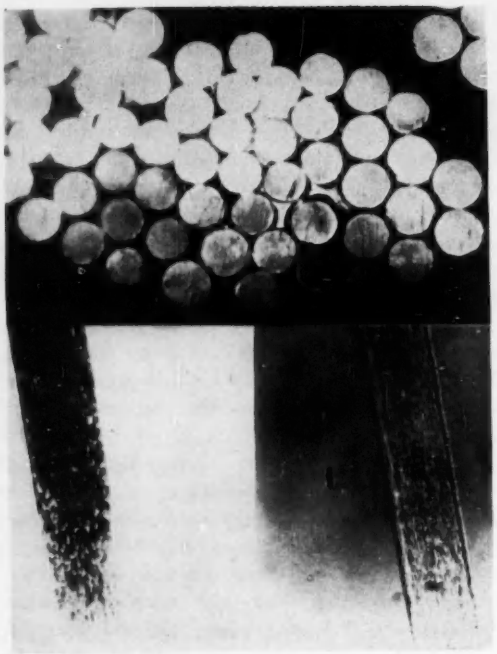

Fig. 6. Photomicrograph of polypropylene multifilament yarn (3-den. individual filament). Top, cross section; bottom left, clear; bottom right, pigmented.

Melt-extrusion was of course the first production method to be considered, because the present production of polyethylene and of polypropylene filaments is being done this way. By drawing on the experience with the older thermoplastic textile fibers, equipment can be adapted to the production of fibers down to 3 den.; perhaps lower. The characteristics of such fibers approach those described above for the monofilaments of heavier gauge.

Figure 6 shows the magnified photos of the cross sections of a polypropylene multifilament yarn and of the side views of individual filaments, unpigmented and pigmented.

Solution-spinning is the other possibility; patents granted in Europe to at least two different concerns indicate that such methods are being seriously considered. The solution of polymer in high boiling paraffinic or naphthenic hydrocarbons is spun at temperatures of 150–180° C. (around 300° F.) and the extruded filaments solidified either by hot air or by precipitation in liquids such as ethyl alcohol or acetone. Filaments of 4–7 g./den. tenacities are obtained. The near future may show which will be the industrial method to give the better or more economical fiber.

Conclusion

We have seen the tremendous flexibility in characteristics which are offered by the polyolefins. Substantial developments are reached or known to date and we can surmise what is in store. Polypropylene and its future relatives have a good chance to be successful as textile fibers, provided close cooperation is established between the manufacturer of the polymers, the processor to fibers, and the converter into the textile end products; this means the industrial philosophy which made the nylons, acrylics, and polyesters the textile fibers they are.

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The Effect of the Short Fibers in a Cotton on its Processing Efficiency and Product Quality

Part I. Affecting the Short Fiber Content by the Addition of Cut Cotton Fibers[1]

John D. Tallant, Louis A. Fiori, and Dorothy C. Legendre

Southern Regional Research Laboratory,[2] New Orleans, Louisiana

Abstract

The effect of the short fiber content of a cotton on yarn and fabric properties and processing efficiency, long a speculative and controversial subject, is investigated to a limited extent in this paper by the technique of cutting sliver into and ¼- and ½-in. segments and adding the resulting short fibers to the parent cotton. The results indicate that increases in short fibers are detrimental to virtually all yarn and fabric properties and require increased roving twist for efficient drafting during spinning. A 1% increase in fibers shorter than ⅜ in. causes a strength loss in yarns of somewhat more than 1%. The quantities of cotton processed for this paper were insufficient to draw conclusions on neps, waste, or processing efficiency. The effect of short fibers on these properties will be considered in subsequent papers.

Introduction

Cotton, being an agricultural product, is subject to environmental and varietal variation in its important fiber properties. A single measure of length, classer's length, has long been used as an important criterion of a cotton's spinning value. However, it is well known that two cottons having the same classer's length may have different spectra of length distribution, with one having significantly more short fibers than the other.

The influence of the shorter fibers in the cotton sample on the product quality and processing efficiency has been the source of much speculation but little quantitative examination. This has undoubtedly been the case primarily because of the great difficulty and time consumption involved in physically sorting out and measuring the various fiber length classes by techniques such as the Suter-Webb sorter.

Sullivan [13] and Gregory [7] in their separate works appear to approach the problem by "discounting" to some extent the short fibers in their theoretical analyses. They do this by increasing the mean length (which was initially lowered by the short fibers) by an amount based on the standard deviation of the sample. This can be at best an approximation, due to variations in the length distribution and the fact that the length distribution, even on a weight basis, is seriously skewed.

More recently, Navkal [11], apparently using length array data, has asserted that "fiber length irregularity percentage appears to contribute very little towards the single thread strength." The measure of fiber length irregularity was defined as that "percentage which is the percentage by weight of fibers shorter than three-fourths of the mode." By use of his basic definition, in the case of most American Upland cottons, the fiber length irregularity percentage would include all fibers shorter than at least ¾ in. Probably the negative result reported was because of the inclusion of medium length fibers, which apparently contribute considerably to yarn strength.

Using a different measure, the Fibrograph length uniformity ratio, Webb [14] in an extensive statis-

[1] Presented at the Cotton Research Clinic of the National Cotton Council of America, May 12, 1959.

[2] One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture, New Orleans, Louisiana.

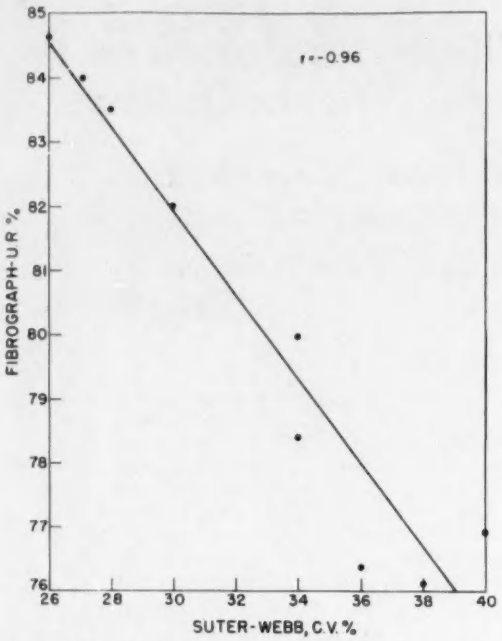

Fig. 1. Relationship between uniformity ratio and array coefficient of variation.

tical analysis with other fiber properties concludes that "length uniformity index made only a negligible effect on single strand count × product." However, the authors of this paper, using the fiber data on the 43 cottons used by Fiori et al. [5] when attempting to make a correlation and a plot between Fibrograph[3] length uniformity ratio and Suter-Webb length coefficient of variation, found a rather poor relationship. Yet Figure 1 shows the data from Hopper and Tallant [8] in which the coefficient of variation was obtained from two arrays and the Fibrograph length uniformity ratio was the mean of 100 determinations for each of the nine cottons. A very good relationship is found. Therefore, one is led to conclude that the normal number of observations made to determine the length uniformity is insufficient for reliable results.

In earlier work Webb and Richardson [15] had reported from an analysis of 766 cottons that yarn properties were definitely affected by the Suter-Webb length coefficient of variation. The larger coefficients were associated with a general deterioration in yarn properties, and it may be reasonably inferred that the larger coefficients of length variation indicated to some extent larger amounts of short fibers.

Köhler [9] has indicated that the "length of slippage" is approximately 8 mm. or slightly more. By this he meant that fibers 8 mm. or less are likely to slip rather than break when a yarn ruptures. Hence these short fibers could contribute little to strength. With the Suter-Webb array a division point between two cells is $\frac{3}{8}$ in., or 9.5 mm. The $\frac{3}{8}$-in. value was chosen for an initial survey of existing fiber data. By use of the 43 cottons studied by Fiori et al. [5] an analysis was made of the array data to determine the short fiber content in this series. It was found that the percentage weight less than $\frac{3}{8}$ in. varied from 2.5% to 12.5%, or a ratio of 5:1. The average value was 6.7%. It should thus be noted at the outset that the short fiber content of commercial cotton can vary over a wider ratio than any other important fiber property. Closer examination showed that the cottons with the extremely low short fiber content were of the Sea Island or kindred varieties. Within the Upland varieties a minimum of about 3.5% was found. While a maximum of about 12.5% was observed for this series of cotton ginned prior to 1954, there is increasing evidence that new ginning practices necessitated by mechanical harvesting have led to increased fiber breakage and a consequent increase in the short fiber content [6]. On the other hand, higher processing speeds and increased work loads, adopted by textile mills to lower costs, have imposed greater requirements on the processing properties of cotton.

Although the short fiber content changed over a range of 5:1, the length coefficient of variation changed only from 22 to 37%, or a ratio of 1:1.7. The length CV is influenced by all length groups and the degree of skew and is thus somewhat insensitive to short fiber content *per se*. To show the relatively small influence of the short fibers on the usually measured fiber length properties, consider the following example of a typical cotton with 6.8% short fibers in which the array data was recomputed as if there were no fibers less than $\frac{3}{8}$ in. at all.

	Upper quartile, in.	Mean length, in.	Coef. of var., %
Natural distribution	1.31	1.09	29
$\frac{3}{8}$ in. and less eliminated	1.32	1.12	24

[3] Use of a company and/or product named by the Department does not imply approval or recommendation of the product to the exclusion of others which may also be suitable.

Consequently, for this investigation it was decided to use as objective a measure as possible. The Fibrograph uniformity ratio and array coefficient of variation were considered unsuitable for the reasons given above. Therefore, guided by Köhler's work, the percent weight less than $\frac{3}{8}$ in. was selected as a measure of short fibers for all work in connection with this investigation and is the definition of the term "short fibers."

Experimental Procedure

Table I was compiled to show the levels of short fiber content which might be expected under various circumstances. It will be seen that combing affords a means of achieving a relatively low level of short fibers, although certain specially selected strains of cotton have approximately that level initially. Double combing achieves a still lower level. This procedure is quite laborious, but may afford a mechanical means for obtaining reasonable amounts of lint with very low short fiber content. On the other hand, differential or partial ginning offers the best possibility of obtaining differing levels from the same lot of seed cotton. Results with the use of this technique will be discussed in later papers of this series.

For the phase reported on in this paper, a cotton with genetically low short fiber content was sought with the view that short fibers could then be added in various levels and thereby cover the range. About 150 lb. from each of two bales of Bobshaw cotton was used. The short fiber content of each was low, and fortuitously the two lots differed widely in fiber elongation. Therefore the two cottons were processed in identical manner, thereby affording not only a replication of the effect of short fibers but also evidence as to whether there is any interaction due to the fiber elongation characteristics.

Short fibers were obtained by processing small amounts of each of the two cottons into sliver, which was then passed through a conventional top cutting machine of the sort used in the worsted industry. The same general technique was used and described by Fiori and Brown [3]. The cutters were set to give $\frac{1}{4}$-in. cut segments of sliver and then reset to give $\frac{1}{2}$-in. segments. It should be borne in mind that due to nonparallelization and doubling of fibers there was an appreciable percentage longer than the nominal cut length. Of course, there were many fibers shorter than the nominal length. Nelson et al. [12] have recently reported work showing the alteration of length distribution and its effects by use of similar techniques.

TABLE I. Levels of Short Fiber Content and Techniques for Obtaining Them

Technique	Short fibers less than $\frac{3}{8}$ in., % (wt.)
Manually plucked from seed cotton	1
Machine double combed	1.5
Machine single combed	2.5
Manually combed from seed cotton	2.5
Genetic selection, no short fiber added	3–3.5
Manually ginned from seed cotton	4
Machine ginned (partially, first pass)*	4
Machine ginned (normal)	7
Various percentages of short fiber added	8–20
Machine ginned (partially ginned, subsequent passes)*	12–20

* Partial or differential ginning, a technique in which only a fraction of the fibers on the seed are removed in the first pass through gin. In subsequent passes the remainder of the lint may be removed.

The short fibers were carefully mixed into the parent cotton on the picker apron in approximately 7-lb. lots for each short fiber level. Besides the control, three levels of short fiber content spaced across the practicable range were desired. Therefore, 7, 14, and 21% fibers by weight from the cut sliver were added. These percentages were made up of fibers from either $\frac{1}{4}$-in. or equal parts of $\frac{1}{4}$- and $\frac{1}{2}$-in. segments. The lots were then normally processed; samples were taken at the second drawing for fiber analysis because it was recognized that there might be considerable removal of such artificially added fibers in the card. The short fiber content at second drawing is the basis for all calculations, graphs, and conclusions. These and other pertinent fiber data are given in Table II.

Samples of picker laps from each cotton, consisting of the natural distribution and three higher levels of short fiber content, were classed. The results are included in Table II and seem to indicate that cotton classers apparently disregard the presence of even quite high levels of short fiber content.

Substantiating the theoretical data presented in the introduction, the upper quartile length is very stable, despite mean length decreases, even with the inclusion of large amounts of short fibers. A similar observation can be made for the Fibrograph upper half mean length, while the uniformity ratio shows a tendency to decrease by a few percentage points. The Micronaire, Stelometer tenacity, and Stelometer

TABLE II. Fiber Properties of Second Drawing Sliver of Bobshaw Cottons Showing the Effects of the Addition of Short Fibers

Short fiber content, % wt. less than $\frac{3}{8}$ in.	Classer		Length							Strength, Stel. $\frac{1}{8}$ in., g./tex	Elongation, Stel. $\frac{1}{8}$ in., %
			Suter-Webb			Fibrograph					
	Length, in.	Grade	UQL, in.	M, in.	CV, %	UHML, in.	M, in.	UR, %	Micronaire reading		
High elongation											
Control and control with $\frac{1}{4}$-in. cut sliver added											
3.65*	—	—	1.22	1.04	25	1.16	.96	83	4.6	21.8	10.3
8.55	—	—	1.22	1.00	43	1.17	.96	82	4.7	22.0	10.4
11.50	—	—	1.21	.98	35	1.16	.94	81	4.7	21.7	10.1
19.48	—	—	1.19	.90	43	1.16	.92	79	4.7	22.0	10.0
Control and control with $\frac{1}{4}$- and $\frac{1}{2}$-in. cut sliver added											
4.42*	$1\frac{3}{32}$	M(Lt.Sp.)	1.22	1.04	27	1.16	.97	84	4.7	21.4	11.5
6.67	$1\frac{3}{32}$	M(Lt.Sp.)	1.21	1.00	30	1.16	.96	83	4.8	21.1	10.4
8.37	$1\frac{3}{32}$	M(Lt.Sp.)	1.22	.99	33	1.15	.93	81	4.7	21.1	10.7
11.88	$1\frac{3}{32}$	M(Lt.Sp.)	1.20	.93	38	1.12	.83	74	4.7	21.2	10.7
Low elongation											
Control and control with $\frac{1}{4}$-in. cut sliver added											
2.90*	—	—	1.15	1.00	23	1.10	.92	84	5.2	21.9	7.4
8.68	—	—	1.13	.92	31	1.08	.92	85	5.3	20.6	7.7
13.75	—	—	1.12	.88	36	1.08	.90	83	5.2	21.7	7.7
16.49	—	—	1.12	.87	39	1.08	.87	81	5.2	21.3	7.4
Control and control with $\frac{1}{4}$- and $\frac{1}{2}$-in. cut sliver added											
3.37*	$1\frac{1}{16}$	SLM	1.15	.98	24	1.09	.90	83	5.3	18.6	7.3
5.92	$1\frac{1}{16}$	M	1.15	.95	29	1.08	.88	81	5.3	18.8	8.1
8.46	$1\frac{1}{16}$	M	1.15	.93	32	1.08	.86	80	5.3	19.3	7.9
12.73	$1\frac{3}{32}$	M	1.12	.86	39	1.05	.82	78	5.3	20.3	6.9

* Control—no addition of short fibers.

fiber elongation are similar regardless of the addition of the short lengths cut from the parent cotton. This would be expected, since cutting should not affect the air porosity, while for the strength and elongation measurements the shorter fibers are largely combed out before testing.

Since the performance of arrays to determine the short fiber content as a usable statistic is relatively novel, it was necessary to set operator tolerances and determine the precision with which the short fiber content could be found. A brief survey of duplicated array data indicated that a reasonable operator tolerance between two individual arrays for percent of fibers less than $\frac{3}{8}$ in. would be 1.5%. After establishing this tolerance, the operators, by paying somewhat more than usual attention to the shorter fibers, were able to stay consistently within the tolerance and indicated that a somewhat stricter tolerance would be feasible.

The approximately 7-lb. lots processed were too small to give reliable indications of waste.

Each lot of cotton was spun[4] into 14/1 (42), 22/1 (27), and 36/1 (16) at twist multipliers of 3.5, 4.0, 4.5, 5.0, 5.5, and 6.0.

All physical tests were conducted under standard atmospheric conditions and in accordance with ASTM recommendations. Skein strength determinations were made on a pendulum-type tester of 0–150 lb. capacity [1a], and single strand strength and elongation at break values were obtained with an automatic Uster single strand tester.[3] Fiber strength and elongation properties were measured on the Stelometer; all other fiber properties were determined by ASTM methods [1b]. Yarn appearance grades were obtained by using ASTM methods [1a] and yarn uniformity was measured with a Uster instrument.

Small amounts of 23/1 (26) at 3.80 T.M. of each lot of cotton was included as filling in a common warp. The fabric was a 64 × 64 Type 128 sheeting; further details of this fabric are reported by Fiori

[4] Figures in parentheses are approximate tex values.

et al. [4]. The quantity of fabric produced from each lot of Bobshaw cotton with varying levels of short fibers was three yards or less; therefore the test results are very limited in scope because of the limited yardage and, more importantly, because the yarn of the test cottons was inserted only as filling. Replications along the roll of fabric were, of course, precluded because the limited yardage for each lot was woven as a single block.

Results and Discussion

The roving size selected was 2.0 H.R. (300 tex) and for each lot sufficient twist was inserted for efficient drafting during spinning [2]. A plot of the roving twist required against short fiber content is shown in Figure 2. The two cottons behaved similarly but at different levels; that is, as the short fiber content increased somewhat greater twist was required. The difference in level is attributed to the difference in classer's length of the two cottons, which it will be recalled did not change with the addition of short fibers. Because of the increase in twist required by the samples with the highest short fiber contents, their production rates were about 10% less than for their controls.

The twist vs. count-strength product curves for the three yarn sizes spun from the 16 lots of cotton were in general smooth and showed a uniform decrease in strength with increasing levels of short fibers. More surprising, there appeared to be no tendency for the twist for maximum strength to change significantly as the short fiber content was increased. Representative skein twist vs. count-strength product curves are shown in Figure 3.

The maximum skein count-strength product for each lot spun into 14/1 (42) is plotted against short fiber content in Figure 4. This figure shows that while the high and the low elongation cottons had different levels of strength, the rates at which their maximum strength is degraded by the addition of

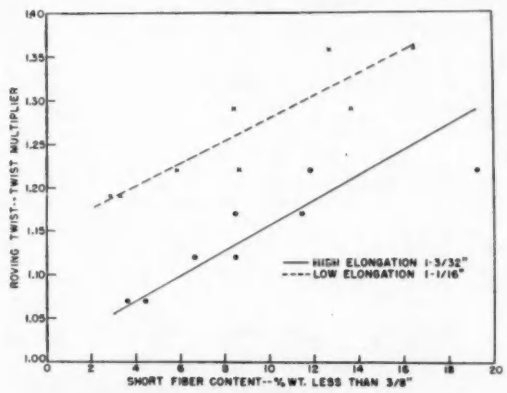

Fig. 2. The effect of short fiber content on roving twist multiplier required for efficient drafting during spinning of 2.0 hank roving (300 tex).

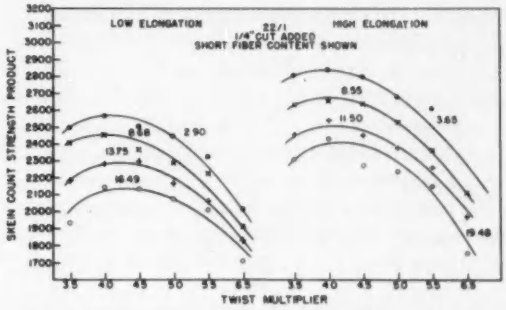

Fig. 3. Typical twist vs. count-strength product curves for 22/1 yarn, showing the effect of addition of short fibers (¼-in. cut).

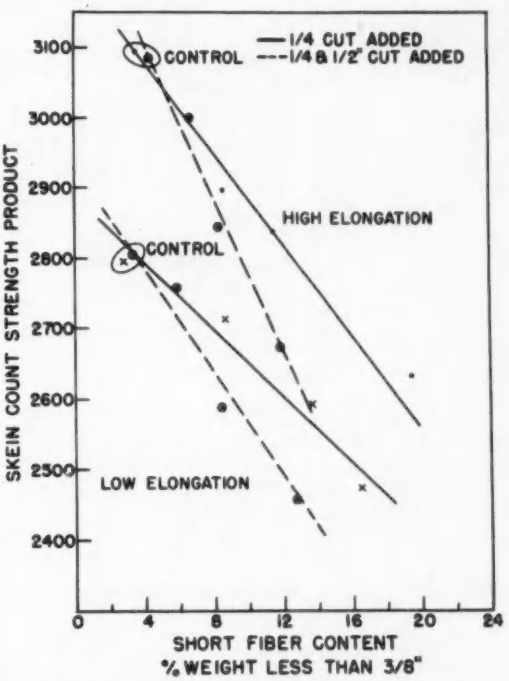

Fig. 4. The effect of the addition of short fibers on the maximum skein count-strength product of 14/1 yarn.

short fibers is similar. A somewhat steeper rate of strength loss is observed for the samples which contained a combination of ¼- and ½-in. cut fibers. This means that the addition of fibers slightly longer than ⅜ in., which are not taken into account in the short fiber content, also has some degrading effect on yarn quality.

The general pattern shown for the 14/1 (42) in Figure 4 held true for the 22/1 (27) and 36/1 (16) yarns; the yarns spun from the high elongation cotton had higher skein count-strength products. However, since it is the degradation of strength with the addition of short fibers which is the chief interest in this paper, Figures 5 and 6 show skein count-strength product plotted as percentages of the control for the two finer counts. These plots show that the count-strength products decreased somewhat more than 1% for each 1% increase in short fiber content.

TABLE III. Single Strand Strength Coefficients of Variation Averaged Over All Six Twist Multipliers for Each Yarn Number from Each Cotton

Short fiber content, % wt. less than ⅜ in.	Yarn size 14/1	22/1	36/1
High elongation			
Control and control with ¼-in. cut sliver added			
3.65*	7.3	10.0	10.9
8.55	8.2	10.0	11.2
11.50	8.7	10.7	12.8
19.48	9.8	11.3	13.6
Control and control with ¼- and ½-in. cut sliver added			
4.42*	8.5	9.8	11.9
6.67	8.2	10.3	13.4
8.37	8.7	10.7	14.0
11.88	9.9	11.6	13.3
Low elongation			
Control and control with ¼-in. cut sliver added			
2.90*	8.7	10.4	13.8
8.68	9.9	10.9	13.2
13.75	10.2	11.9	14.2
16.49	10.5	12.4	14.3
Control and control with ¼- and ½-in. cut sliver added			
3.37*	9.0	11.1	13.4
5.92	9.2	10.2	13.7
8.46	10.0	11.9	16.1
12.73	10.3	13.3	17.8

* Control—no addition of short fibers.

The high and low elongation cottons plotted in this manner showed no substantial difference and are plotted together for simplicity.

The single strand tenacity data showed a very similar trend to the skein data, and all conclusions drawn from the skein data are valid for single strand data.

The coefficient of variation of strength for individual lots did not show a completely smooth relationship, although in general the trend for all yarn sizes spun from both cottons was for the CV of strength to increase with the addition of short fibers. In order to smooth the relationship and render the data more compact, the CV for each level of short fiber content averaged over the six twist multipliers in each size were plotted in Table III. This table shows conclusively that increasing the level of short fiber content increases the yarn strength coefficient of variation.

Yarn single strand elongations showed the normal tendency to increase linearly with increasing twists. Furthermore, for a given twist the breaking elongation showed a uniform tendency to decrease with the

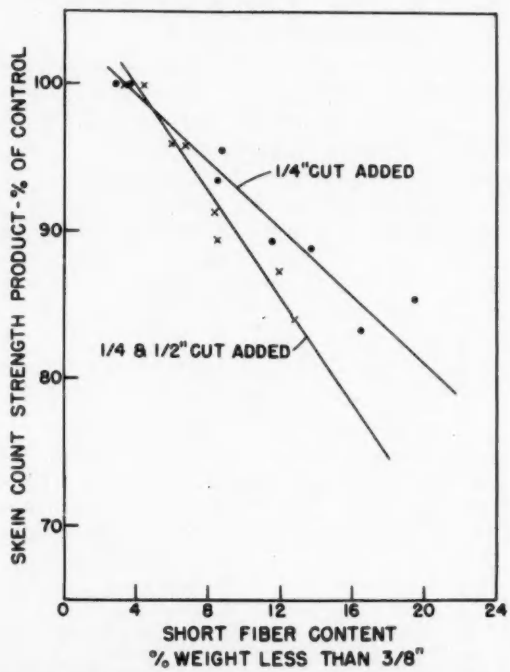

Fig. 5. Effect of increasing short fiber content on skein count-strength product for 22/1 yarn plotted as percentage of control.

addition of short fibers. Table IV shows the breaking elongations for the 22/1 (27) 4.0 T.M. yarns and the associated single strand tenacity. It is problematical whether the reduction of breaking elongation is due to short fibers directly, their effect on evenness, or an interaction due to the reduction of breaking strength. It may be postulated that the modulus of the yarn is unchanged by the presence of short fibers; hence if the short fibers cause a premature break the ultimate elongation must be similarly curtailed. However, when the yarn containing the highest level of short fibers was compared with its control, for both the high and low elongation cottons, it was found that the single strand tenacity had decreased 14% while the breaking elongation had decreased only 10%, averaged over all twists and counts. Thus it may be concluded that the short fibers are exerting some influence on the secant modulus as well as the breaking strength.

Table V shows the Uster evenness data for one twist for all yarns. Uniformly the evenness was lowered as short fibers were added. Similarly, when yarn grading boards were made for a representative twist for all lots of cottons and graded by a panel, the results showed a decrease from about A− to C+, as shown in Table VI. It will be observed that these yarns show a large change in appearance index for a rather small change in Uster uniformity. A possible explanation is given by Langhorn and Sondhelm [10]: "the . . . results show that differences in evenness between yarns, which are quite small in terms of electronic evenness values, are detectable by blackboard examination."

Interpretation of the yarn data shows that there is no noticeable interaction due to fiber elongation. In general, yarn strengths, whether single strand or skein, and their decrease with the inclusion of short fibers, followed similar patterns regardless of fiber

TABLE IV. Single Strand Elongation and Tenacity of 22/1 (27) 4.00 T.M. Yarn

Short fiber content, % wt. less than ¾ in.	Elongation, %	Tenacity, g./tex
	High elongation	
	Control and control with ¼-in. cut sliver added	
3.65*	6.65	16.9
8.55	6.73	15.9
11.50	6.49	15.3
19.48	6.15	14.6
	Control and control with ¼- and ½-in. cut sliver added	
4.42*	6.65	16.8
6.67	6.55	16.0
8.37	6.55	15.5
11.88	6.15	14.7
	Low elongation	
	Control and control with ¼-in. cut sliver added	
2.90*	5.60	15.0
8.68	5.25	14.5
13.75	5.20	13.8
16.49	5.05	12.5
	Control and control with ¼- and ½-in. cut sliver added	
3.37*	5.40	15.0
5.92	5.45	14.8
8.46	5.45	14.2
12.73	5.05	13.1

* Control—no addition of short fibers.

TABLE V. Uster Yarn Uniformity (%; 4 yd./min.) as Influenced by Short Fiber Content

Short fiber content, % wt. less than ¾ in.	Yarn number		
	14/1	22/1	36/1
	High elongation		
	Control and control with ¼-in. cut sliver added		
3.65*	12.2	15.4	14.0
8.55	12.5	16.0	14.8
11.50	12.9	16.6	15.4
19.48	13.8	17.9	16.5
	Control and control with ¼- and ½-in. cut sliver added		
4.42*	12.5	15.5	14.2
6.67	12.2	16.5	14.7
8.37	12.7	16.5	15.2
11.88	13.7	16.6	15.7
	Low elongation		
	Control and control with ¼-in. cut sliver added		
2.90*	11.6	15.8	14.6
8.68	12.3	16.5	15.4
13.75	12.6	17.4	16.1
16.49	12.9	17.7	16.6
	Control and control with ¼- and ½-in. cut sliver added		
3.37*	12.1	16.5	14.5
5.92	12.9	17.1	15.0
8.46	13.1	17.1	15.7
12.73	13.2	18.5	16.4

* Control—no addition of short fibers.

elongation and tended to reflect their respective fiber tenacities. In the case of single strand elongation the fiber elongation was reflected in the level for their respective yarns; however, the behavior with the addition of short fibers was similar. Therefore, it may be concluded that for the purposes of this study the two Bobshaw cottons, while having different levels of fiber elongation, can be considered as replicating each other in demonstrating the effect of the inclusion of short fibers.

Fabrics

The fabrics with both the high and low elongation cottons showed a progressive deterioration of all fabric properties tested as the short fiber content was increased. A possible exception was the decrease in air permeability with an increase in short fibers; this could be either desirable or undesirable depending on end use. This particular effect is attributed to the undoubtedly greater "hairiness" of the filling yarns with greater short fiber content. However, strip breaking strength, tear resistance, and flex abrasion were all degraded by approximately equal or greater percentages than the strength degradation noticed in the yarns. Table VII shows the fabric filling properties for the control and the highest level of short fiber content. It will be noted that except for strip elongation the fiber elongation does not appear to affect the results.

TABLE VI. Yarn Appearance Grades as Influenced by Short Fiber Content

Short fiber content, % wt. less than $\frac{3}{8}$ in.	Yarn number 14/1	22/1	36/1	Average
	High elongation			
	Control and control with $\frac{1}{4}$-in. cut sliver added			
3.65*	A−	A−	B+	A−
8.55	B+	A−	B−	B+
11.50	B	B+	C+	B
19.48	C+	B	C	C+
	Control and control with $\frac{1}{4}$- and $\frac{1}{2}$-in. cut sliver added			
4.42*	B+	A−	B+	B+
6.67	B+	A−	B	B+
8.37	B	B	C+	B−
11.88	B	B+	C+	B
	Low elongation			
	Control and control with $\frac{1}{4}$-in. cut sliver added			
2.90*	B+	A	B+	A−
8.68	B+	B+	B+	B+
13.75	B+	B	B−	B
16.49	B−	C+	C	C+
	Control and control with $\frac{1}{4}$- and $\frac{1}{2}$-in. cut sliver added			
3.37*	B+	B+	B	B+
5.92	A−	B	B+	B+
8.46	B+	B	A−	B+
12.73	B	B	B−	B

* Control—no addition of short fibers.

Summary

Where short fibers are defined as those fibers $\frac{3}{8}$ in. and shorter and hence those not likely to break when the yarn ruptures, it appears that the following conclusions may be drawn.

1. Short fibers are detrimental to yarn strength, both skein and single strand, and to virtually all fabric properties.

2. Increasing levels of short fiber content, while decreasing the maximum strength available from a cotton, do not appear to affect the yarn twist required for maximum strength. However, increased

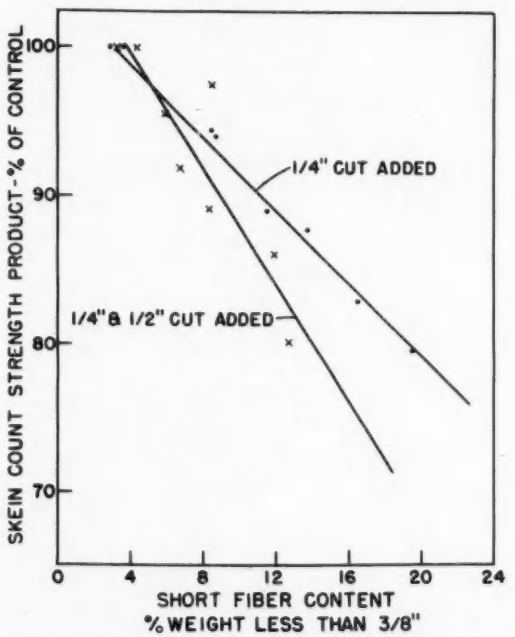

Fig. 6. Effect of increasing short fiber content on skein count-strength product for 36/1 yarn plotted as percentage of control.

TABLE VII. Filling Fabric Data for Control and Highest Level of Short Fiber Content

Short fiber content, % less than ½ in.	Fabric weight oz./yd.²	Crimp, %	Strip		Flex abrasion, cycles	Tear resistance		Air permeability, ft.³/min./ft.²
			Breaking strength, lb.	Elong. %		Elmendorf, g.	Tongue, lb.	
				High elongation				
3.65	4.80	6.0	67.4	14.4	1910	1720	4.8	88
19.48	4.76	6.3	57.3	13.6	1460	1410	3.9	77
				Low elongation				
2.90	4.73	5.3	61.8	12.5	1560	1580	4.1	100
16.49	4.74	5.7	55.3	12.7	1240	1370	3.7	93

roving twist is required as short fiber content increases.

3. As a further corollary from this experiment it appears that although the effect of the intrinsic fiber elongation can be readily traced through the yarn and into the fabric state, fiber elongation as measured by the Stelometer at ⅛ in. gauge length has no effect on the conclusions drawn above.

Subsequent papers will deal with microspinning results with very small lots of cotton as well as large pilot plant scale operations on the effect of short fibers on processing efficiency and product quality through finishing and dyeing stages in sufficient quantities to allow sound conclusions to be drawn.

Acknowledgment

The authors wish to express their appreciation to the following members of the Cotton Mechanical Laboratory: E. Kingsbery, A. Callegan, and R. Pertuit for processing the cotton into yarns and N. Roddy for weaving the fabric; L. Leitz and A. Castillon for making the necessary calculations and assistance in preparation of illustrative material; S. Reinhardt for uniformity measurement; and H. Little, Statistician, for help and guidance in pursuing the experiment and analyzing the data. Thanks are also due to the following members of the Instrumentation and Analysis Group: A. Cooper, M. Smith, and W. McSherry for determining the physical properties of fibers, yarns, and fabrics and G. Pittman of the Engineering and Development Laboratory for drawing the charts.

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A Method for Determining the Effects of Various Gin Treatments on the Spinnability of Cotton[1]

Samuel T. Burley, Jr.

United States Department of Agriculture, Agricultural Marketing Service, Washington 25, D. C.

FOR a long time, the ginning industry and the U. S. Department of Agriculture have been striving to develop cleaning and conditioning equipment and ginning techniques that would preserve the inherent quality of the cotton lint of the increasingly large volume of roughly or mechanically harvested seed cotton. As a result, a great majority of the nation's gins have installed various types of equipment for cleaning and conditioning both seed cotton and lint, and many gins have multiple units in excess of recommended levels of practice. Although standard laboratory measurements of cotton do not show that such practices result in significant changes in quality properties other than in grade, mill operators report that possible compounded application or misuse of such gin equipment sharply reduces the spinning performance of cotton, thus increasing processing costs and lowering the value of finished products.

To try to evaluate fully the effects of various gin treatments used on cotton, the Marketing Research Division in cooperation with the Cotton Division, both of the Agricultural Marketing Service, set out to develop and perfect a small-scale spinning test that would accurately evaluate the effects, if any.

Cottons Selected for Performance Test

We obtained samples of cotton from the ginning-spinning test cottons harvested and ginned in the Tulare, California area. These samples of cotton were mechanically harvested from one large field and then ginned as separate lots under 12 different gin conditions, including two levels of overhead equipment, each with two levels of heat application, representing three levels of lint cleaning for each level of heat application.

These cottons were spun in the Cotton Division laboratory at College Station, Texas, in accordance with procedures developed for this experimental work.

[1] Presented at the Cotton Research Clinic sponsored by the National Cotton Council of America at Asheville, North Carolina, May 12–14, 1959.

Procedure

A recent publication, "A Method of Evaluating Spinning Performance of Cotton" (Preliminary Report), AMS Series 299, released in February 1959, describes the procedure; it is briefly outlined below.

The method of approach is based on the common knowledge that the finer the yarn size spun from the same cotton, under the same organization and conditions, the greater number of end breakages per hour.

It is essential that the processing equipment used with this test method be in good mechanical condition at all times and remain constant for the entire test. The preparatory processes of opening, picking, carding, drawing, and roving must be set up and operated so that uniform roving is provided for the performance tests made in the spinning process. In order to obtain uniform and reproducible results, the 84-spindle spinning frame with 1½-in. rings used in this test, including the spindles, rolls, rings, creel, etc., must also be set up and operated as precisely as possible.

Because of their effects on spinning end breakages, a number of variables must be held constant in order to obtain comparable results in making a performance test. A constant spindle speed, twist multiplier, and relative traveler weight size must be used on each yarn number spun from all cottons being compared.

Ten pounds of cotton, selected from each of the 12 lots of the California gin-study cottons, were processed identically through the roving process into 3.25-hank roving where each lot of roving was divided equally on 84 roving bobbins. The 84 roving bobbins were creeled in at the spinning frame and fed singly. The spinning frame was operated with a spindle speed of 8500 revolutions per minute. A

constant twist multiplier of 3.95 was used for all yarn spun. The calculated yarn numbers to spin were based on the twist gear used with the spinning frame for a particular traveler weight size as shown in Table I. A series of yarn sizes was spun to obtain a relationship between the actual yarn number produced and the number of end breakages per 1-hr. run after a 15-min. warm-up period. After spinning a minimum of four yarn numbers having an end breakage count of 10 and above, the actual yarn number spun was then plotted against the ends down per 1-hr. run; a trend line was established and drawn as shown in Figure 1. The point where this trend line crosses the 20 ends down/hr. line was defined as the spinnable limit value for this cotton. This spinnable limit value may be converted to a "spinnability index" when a control sample or lot is used, as has been done in this work. The spinnability index is obtained by dividing the spinnable limit yarn number of each lot by the value for the control lot and multiplying by 100. The control sample designated for the gin-study cottons was the cotton receiving the minimum amount of treatment at the gin.

Analysis of Gin Treatment Study

The 12 cottons selected from the California ginning-spinning test were processed under code identification. After the spinning-performance tests were completed, the samples were decoded and arranged in accordance with gin treatments. The results of these tests, which express a spinnability index, are shown in Figure 2.

It can be noted that there are definite trends as to the effect of overhead equipment, lint cleaners, and heat application on the spinning performance of these cottons. The results indicate the following.

1. Elaborate overhead equipment reduced the spinning performance of this cotton ten index points below that of cotton treated with the moderate overhead equipment.

2. Each lint cleaner used in the ginning of this

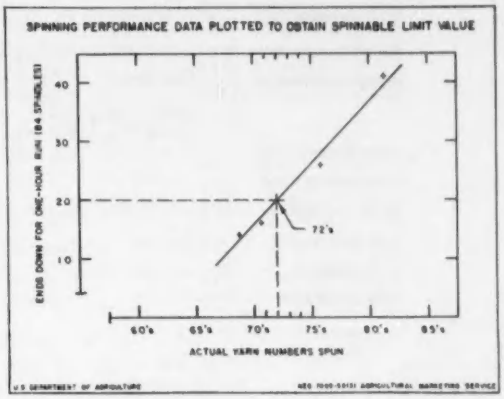

Fig. 1

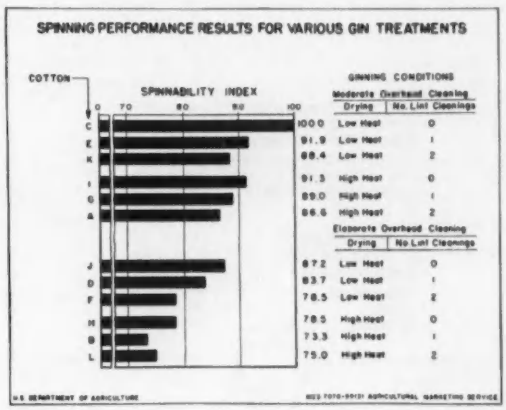

Fig. 2

TABLE I. Work Sheet Used in Making Spinning Performance Tests

Test run	Traveler no.	Yarn number		Twist gear	Draft gear	Ends down		
		Desired	Actual			Left	Right	Total
	15/0	51.9		34				
	16/0	55.05		33				
	17/0	62.42		31				
1	18/0	66.67	68.69	30	38	12	2	14
2	19/0	71.33	70.65	29	37	7	9	16
3	20/0	76.53	75.71	28	34	11	15	26
4	21/0	82.30	81.65	27	32	17	24	41
	22/0	88.74		26				
	25/0	96.0		25				

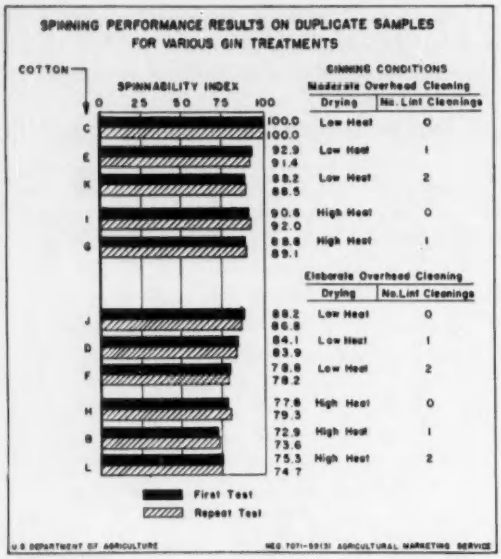

Fig. 3

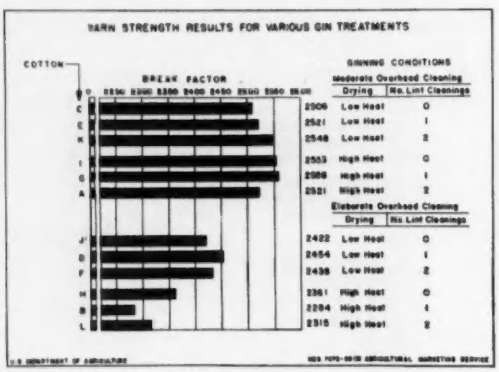

Fig. 4

cotton reduced the spinning performance by approximately four index points.

3. Heat application (high flash heat) reduced the spinning performance of this cotton by four index points, even though the moisture content of the cotton was reduced very little.

4. Excessive application of heat which dries cotton to a very low moisture content accounts for an additional reduction of seven index points.

A repeat test on these cottons was made on 11 of the 12 samples 3–4 weeks later. The "A" sample did not have a repeat test, as the supply of cotton was exhausted in developing the final procedure used

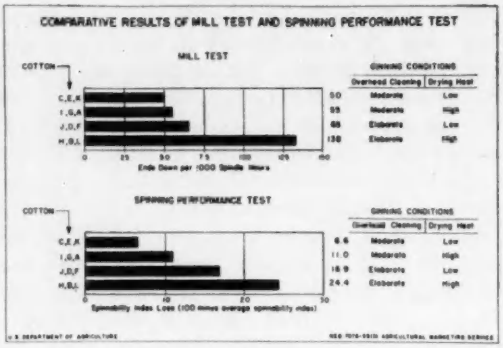

Fig. 5

in this performance test. The results of the first and repeat tests are shown in Figure 3. It will be noted that the trend remains the same. The greatest difference found between duplicate test values was 1.7 index points, noted in the "H" cotton.

The results obtained for the yarn skein strength values expressed as "break factor" or "count-strength product" for these same cottons, in the same perspective as the spinning-performance data, are shown in Figure 4. The break factor was calculated from the average of the 30's and 40's strength data of the laboratory yarns.

This trend is not the same as that for the spinning-performance test, except in the harsher treatments. These results indicate that yarn strength does not necessarily indicate the true spinning performance of cotton for the various gin treatments.

Figure 5 contains the mill-performance data, as well as the spinning-performance-test data, for the various gin treatments combining the zero-, one-, and two-lint cleaners for each gin treatment shown. The mill data show the ends down per 1,000 spindle hours for the four gin treatments, and the spinning-performance-test data are expressed as loss of index points (100-spinnability index) so that the chart trend will be in the same direction.

The trends of these two test methods are similar. We were unable to pick up differences for the effect of lint cleaners on the basis of the mill-test data because of the lack of sensitivity under commercial processing conditions. However, it was possible to pick up differential effects of lint cleaners with the spinning-performance test under controlled conditions, as has been shown earlier in this paper.

Further work to improve this method of spinning-performance test is contemplated. The pilot spinning

research laboratory established cooperatively by the U. S. Department of Agriculture, National Cotton Council, and Clemson College will be used in the method's final stage of development. Samples of cotton and processing results obtained from this laboratory are expected to furnish the necessary information for further evaluating and refining this method of spinning-performance test.

A Miniature Spinning Test for Cotton[1]

C. B. Landstreet, P. R. Ewald, and T. Kerr

Agricultural Research Service, Crops Research Division, Cotton and Cordage Fibers Research Branch, Tennessee Agricultural Experiment Station, Knoxville, Tenn.

Introduction

The U. S. Department of Agriculture Spinning Laboratory at the University of Tennessee in Knoxville is responsible for the early generation evaluation of the spinning performance of new cottons grown in the ARS–Experiment Station cooperative breeding program. In many instances a limited amount of lint is available for testing purposes. Methods of processing and testing have been developed into a routine spinning test requiring only ½ lb. of cotton.

Research in several branches of cotton technology was necessary to make the test successful. Standard equipment was modified, and new small scale machinery and specialized testing apparatus were designed and built. When a practical spinning test was worked out it was necessary to bring the variability in results within allowable limits based upon the precision required by the breeding program.

The object of this paper is to give a broad description of the methods, instruments, and basic ideas involved in a miniature testing program, but not to give detailed instructions as to how the test is made.

Background of Miniature Spinning Test

Prior Laboratory Spinning Tests

Small scale spinning tests were first developed in England by W. L. Balls and his associates during the 1920's. These spinning tests were modified to evaluate cotton varieties and new strains in breeding programs under test in India; at Giza, Egypt; and at the Shirley Institute, Manchester.

In the United States, the Agricultural Marketing Service developed both carded and combed yarn spinning tests which use approximately 5–10 lb. lint. Conventional equipment and testing procedures are used. The usual practice in these AMS Laboratories at Clemson and College Station is to spin two yarn numbers for breeding material.

Because much of the breeding program material had been spun in the AMS Laboratories, in development of a miniature spinning test, continuity was preserved by starting with procedures similar to those employed by AMS.

The 1-lb. Spinning Test

The first test developed at Knoxville required an initial sample size of 1 lb. of lint cotton. A special machine was needed to open and clean such a small sample. The miniature opener-cleaner, to be described later, was developed to fill this need.

The 1-lb. sample was opened and made into a 14-oz. lap by hand on a special feed tray attached to the card. The 55-gr. (3.90 ktex) card sliver produced was drawn twice, using six doublings at each process, to give a finisher drawing sliver of the same weight. This sliver was divided into 10 equal parts by weight and made into a 3.25 hank (182 tex) roving. The roving was double creeled for spinning into 22s and 36s (27.0 and 16.4 tex) yarn. Twenty breaks of standard 120-yd. skeins were used to test the yarn for strength.

[1] Presented at the Cotton Research Clinic, Asheville, North Carolina, May 12, 1959.

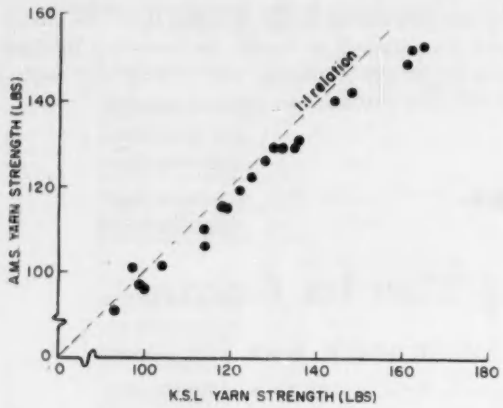

Fig. 1. Comparison between the AMS and Knoxville laboratory 1-lb. spinning tests.

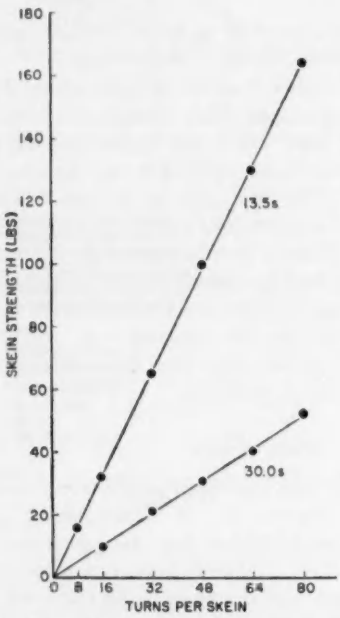

Fig. 2. Relation between number of turns in the skein and observed strength for 13.5s and 30.0s yarn.

Comparisons were made between the 1-lb. test and the standard 5-lb. tests of Clemson and College Station. Twenty-one samples were spun at both laboratories, with the results shown in Figure 1. The higher level of the results from the 1-lb. test can be attributed to the differences in processing in the two laboratories.

The 1-lb. test, while it followed the classic style,

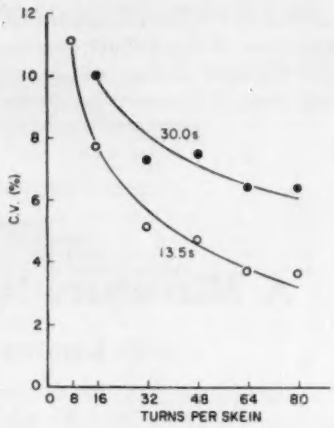

Fig. 3. Relation between number of turns per skein and the coefficient of variation of breaking strength for 13.5s and 30.0s yarn.

was slow, inefficient, expensive, and used too large a sample for early screening work. It was used for two years, and during this time the idea of spinning only one yarn number and predicting the strength of other desired numbers evolved. It was shown in work published in 1954 [1] that yarn skein strength is linearly related to the reciprocal of the yarn count when the yarns are processed at optimum conditions and spun for maximum strength. With this fact established, a new miniature test was developed.

Development of the ½-lb. Spinning Test

Factors Considered

Three factors had to be considered in developing the new spinning test. First, it was necessary to determine the minimum amount of lint that could be efficiently processed on conventional equipment. Second, the smallest representative sample that a plant breeder could be expected to obtain had to be determined; third, a method had to be developed for rapidly determining yarn strength.

Experiments showed that ½ lb. of cotton could be processed efficiently and was also the smallest reliable sample that could be easily obtained. The adoption of such a small sample required a new method for measuring yarn strength because there was not enough yarn for a standard skein test.

Development of the Miniature Skein

In 1946, Lewis [5] experimented with skeins wound on a standard reel, varying the number of

turns from 8 to 80. He concluded that skeins having considerably less than 80 turns were adequate for determining yarn number and strength.

Lewis' experiments were repeated and expanded at the Knoxville laboratory, with results similar to those he had reported. Yarn strength was plotted versus number of turns in the skein for 13.5s and 30s (44.0 and 19.7 tex) yarn, as shown in Figure 2. It can be seen that there is a good linear relation between the observed strength and the number of turns. The coefficient of variation among breaks was plotted against the number of turns per skein, as shown in Figure 3. These curves approximate the expected decrease in percent CV with increase in number of turns per skein.

In order to conserve yarn, a miniature skein 20 in. in circumference with 20 turns was selected. A reel was built for winding the small skeins and an IP-4 tester was modified to break them. The coefficient of variation among breaks was approximately 8%, causing the skein to be rejected for use in the program being developed.

A 40-turn skein was tried next, but could not be broken on the IP-4 tester. The Model J tester was modified to break this skein. The skein proved successful and its characteristics are discussed under Variability in Spinning Test Results. A comparison was made between standard and miniature skeins by reeling both from the same set of bobbins as in the method described by Lewis. Extensive testing was done on 22s (27.0 tex) yarn because this was the number selected for the routine spinning test. A comparison was made for five additional numbers ranging from 60s to 8s (9.85 to 74.0 tex) yarn. These experiments showed that the strength ratio between the standard and miniature skein was 1.84.

Processing Organization

Sampling and preparation. Figure 4 shows the work area and storage racks for the samples. A ½-lb. sample is weighed out when the cotton is received. A fiber sample is taken from which two fibrograms, four Stelometer breaks, and two Arealometer readings are made. The spinning sample is put through the opener one time and is then ready for carding.

Carding. The samples are made into laps by hand on card feed trays, as shown in Figure 5. The standard card was modified by adding double coilers and a lap divider so that two ½-lb. samples are processed at the same time. Two 40-gr. (2.80-ktex) slivers approximately 65 yd. long are produced. Figure 6 shows the double coiler on the standard card.

Fig. 4. Work area and storage racks for preparing the spinning test samples.

Fig. 5. Preparing hand made laps on the card feed trays.

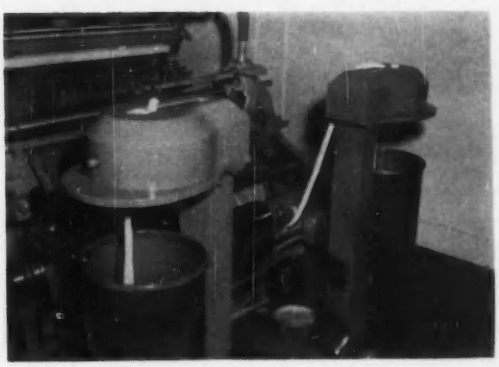

Fig. 6. Double coilers on the standard card.

Drawing. A special one-delivery draw frame is used for both first and second drawing. Six doublings are used while holding both first and second drawing sliver to 45 gr. (3.20 ktex)/yd. The finisher drawing is divided into 10 pieces, each 3 yd. long. Figure 7 is a view of the frame showing the ceiling mirror for viewing the stock at the back from the front of the frame.

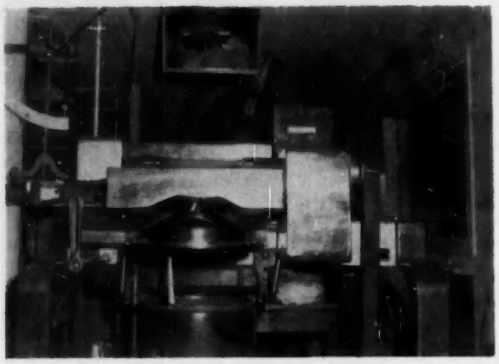

Fig. 7. Front view of the one-delivery draw frame showing the ceiling mirror.

Fig. 8. Miniature opener-cleaner.

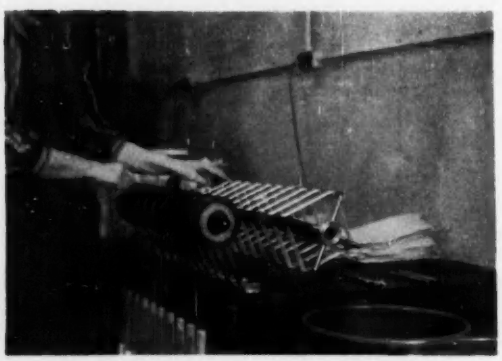

Fig. 9. Miniature skein winder.

Roving. One high draft roving frame is used for making a 1.75-hank (340-tex) roving from the 45-gr. (3.20-ktex) sliver. One doff of 10 bobbins is made for each sample.

Spinning. The roving is single creeled for spinning 105 yd. of 22s (27.0 tex) yarn twisted for maximum skein strength from each of 10 warp bobbins. The spinning frame is a three-roll Casablanca double-synthetic-apron type using 1.5-in. rings and spindle speeds of 9000 rpm.

Testing. Three skeins are wound from each of 10 bobbins and broken on the Model J tester to give 30 breaks per sample.

Special Instruments and Equipment

Miniature Opener

The miniature opener was designed for opening and cleaning very small samples of lint cotton. Figure 8 is a photograph of the opener showing the beater housing, mote box, and collecting box. The beater consists of a shaft on which is mounted eight blades with alternate blades at right angles to each other. Each blade has a pitch angle of 20°. An air flow through the opener is created when the beater is running at its operating speed of 3000 rpm. There are three triangular grid bars located in the bottom of the beater housing. A dead air space is formed by the mote box under the housing. Samples ranging in length from 0.85 to 1.65 in. and in fineness from 300 to over 600 $mm.^2/mm.^3$ have been processed with no damage to the fiber.

Card Trays

The ½-lb. samples are laid out in hand made laps on a two-section pan suspended horizontally behind the card; each section is 19 in. wide and 41 in. long. The pan is raised to 45° when the card is running to feed the lap with a minimum of stretching.

Roving Strength Tester

The roving strength tester [2] was developed for determining the effect of fiber properties, twist, and roving size on roving strength. It is used in the routine testing program when unusual combinations of fiber properties indicate the cotton should not perform normally.

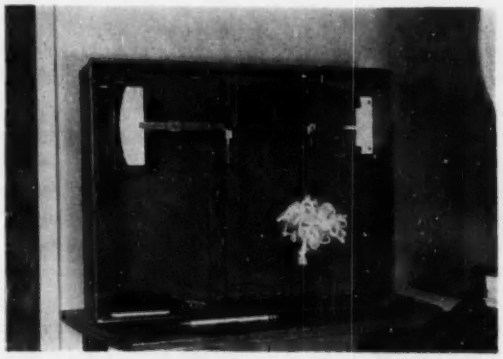

Fig. 10. Direct reading yarn balance for weighing miniature skeins.

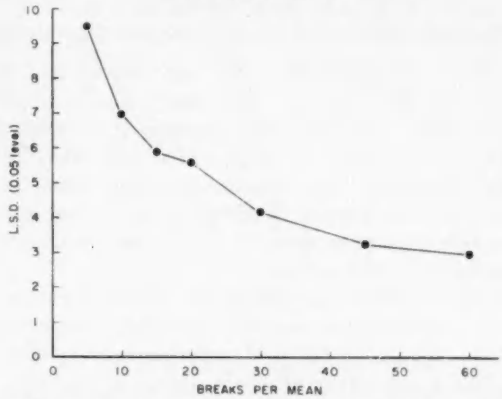

Fig. 11. Graph showing the least significant difference (0.05 level) versus number of breaks per mean for miniature skeins.

Miniature Skein Winder

Figure 9 is a photograph of the miniature skein winder. It was designed to wind skeins of 20 or 40 turns. Ten skeins are wound at the same time with each end tensioned by a magnetic hysteresis brake set for 2 g. The perimeter of the reel is 20 in., giving a length of 22.2 yd. for a 40-turn skein.

Direct Reading Yarn Balance

The yarn balance is shown in Figure 10. It was designed by K. L. Hertel and features an intermittent mechanical damper. The balance was designed to give a direct reading of the yarn number in count or tex when 30, 40, or 60 skeins are weighed.

Gauges

Special gauges were developed for setting the rolls of the drawing and roving frames. The gauges used on the drawing frame were made in the form of spacers that are placed between the roller stands. Those that are not in use are placed between the last stand and a bracket fitted with a bolt for exerting pressure on the roller stands. The stands are not bolted down but are held in place by the top roller weights. The time required to change roller settings was reduced from approximately 20 min. to 6 min. by using the spacers.

Another gauge was built for setting the roving frame rollers. The top apron roll must be properly aligned so as to give a horizontal path to the material through the drafting zones. The gauges are used to position the bottom apron roll and to set the top apron roll so that the aprons will be level.

Special Charts

Nep Count

Neps are estimated by comparing a 50 sq. in. card web sample to a visual nep chart developed at the Knoxville laboratory. The 5 divisions of the chart are: very good, 0–6 neps/100 sq. in.; good, 7–12; fair, 13–24; poor, 25–48; and very poor, 49 or more.

Draw Frame Settings

Two charts are used at the draw frame. One is for determining the roller setting and the other for selecting the draft gear when the length and weight of the input sliver are known.

Roving Twist

The correct twist can be predicted for most cottons from a chart developed at the Knoxville laboratory. The basis for this chart is fiber length (U.H.M.) and fineness ($mm.^2/mm.^3$). It is used for 1.75 hank (340 tex) roving only and at present is not applicable to other roving numbers.

Twist Multiplier for Maximum Skein Strength

Only one twist multiplier can be used with each spinning test sample because of the small sample size and time requirements. The yarns are spun for maximum skein strength, and the optimum twist multiplier is predicted from a graph developed at the Knoxville laboratory [4]. The basis for the prediction is the fiber length and fineness.

Spinning Frame Settings

The chart developed for the spinning frame is used for finding the draft gear when the roving size and twist gear are given.

Manufacturing Performance

The manufacturing performance of a sample is an arbitrary rating based on 100 points for material that gives no roller laps or ends down during processing. Points are subtracted for roller laps and ends down, and it would be possible for a cotton to be rated zero. Points are subtracted as follows for roller laps: one lap, 10; two laps, 20; and three or more laps, 50. Points are subtracted for spinning ends down as follows: zero to two, no points subtracted; three or four, 5; five or six, 10; seven or eight, 20; and nine or more, 50.

No points are subtracted for low yarn strength, grade, or neps because these factors have no bearing on the mill performance of small samples.

Variability in Spinning Test Results

Skein Tests of Homogeneous Material

A well mixed lot of 250 lb. was prepared by thoroughly mixing the seed cotton before ginning. The gin was fed systematically from 10 subdivisions of the original lot. A commercial picker was used for making the laps and the picker feeder was hand fed from four piles to give additional blending.

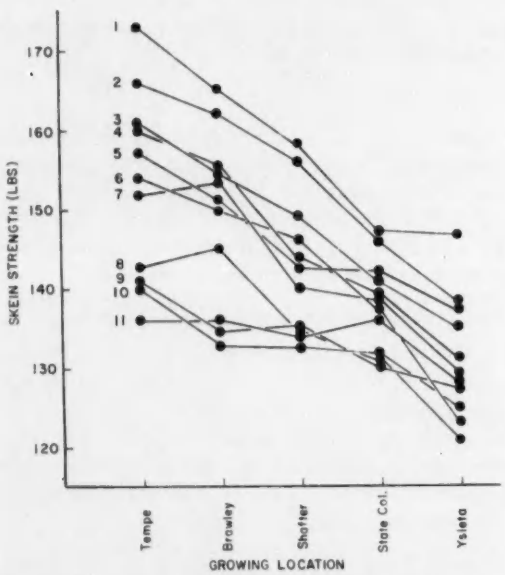

Fig. 12. Graph showing the effect of geographical locations on the yarn strength of eleven cotton varieties; 1, 2302; 2, Cal-7-8; 3, 1028; 4, E-50; 5, 1517BR; 6, E-62; 7, A-4-42; 8, A-44WR; 9, 1017; 10, A-44; 11, R-15-7-1.

Enough cotton was processed from one lap to give 600 miniature skeins of 22s yarn. The skeins were broken on a Model J tester and the strength recorded to the nearest half pound.

Statistical analysis of the data showed that the coefficient of variation among breaks was 4.5%. In Figure 11 the least significant difference of the mean (0.05 level) has been plotted against number of breaks per mean. It can be seen that the fall off of the L.S.D. was quite rapid until a mean of 40 breaks was reached. For early screening of breeding materials and when spinning tests are generally replicated, the mean of 30 breaks gives the required precision.

Replicated Spinning Tests of Homogeneous Material

The well mixed raw stock was sampled into 20 ½-lb. lots for this test. Care was taken to inusre that each sample adequately represented the original lot. The samples were processed as individuals, the only departure from standard procedure being the amount of yarn spun. When all the roving was spun enough yarn was produced to give two sets of 30 skeins from each ½-lb. sample.

The results of this test [3] are shown in Table I. The differences in breaking strength between the first and second set of 30 skeins represents variations within a test. It can be seen that there is little difference in the variation within and between samples.

Use of Spinning Tests in the Breeding Program

The results of spinning tests are used in different ways by different breeders. To understand a single test would require a knowledge of the particular program involved. For this reason the example selected for discussion here is a complete experiment planned jointly and carried out at a number of cotton breeding locations.

Eleven varieties were selected for study and grown in two replicates at five geographical locations; the experiment represented 110 independent spinning tests. The results of the experiment are shown in Figure 12, where skein strength versus growing location is plotted; the effect of environment on the yarn strength of the 11 samples is shown.

Data such as these are useful to the breeders in planning future work for improving and developing new varieties.

Discussion

Atmospheric Conditions

The atmospheric conditions during processing and testing must be held constant when ranking the spinning characteristics of different cottons. All operations in the Knoxville laboratory are carried out at 72° F. and 65% RH. The advantages of operating the laboratory at 72° and at one relative humidity for all processes are numerous. Time is not lost in trying to condition raw material to 58% RH for opening and carding, as done in some laboratories, and then up to 75% for spinning and down again to 65% for testing. An increase in mean temperature from 70° to 72° has no measurable effect on processing characteristics of cotton and allows more comfortable working conditions for operators.

Limitations of the ½-lb. Test

The ½-lb. sample limits the variety of information obtainable. For example, the test will not give an accurate indication of waste percentages, nor will the relatively gentle processing used permit an accurate indication of yarn appearance to be expected from normal mill operations. The test makes no attempt to evaluate the combing efficiency of cotton.

Tex System

The Knoxville laboratory replaced the count with the tex system for numbering sliver, roving, and yarn in 1958. The card sliver is 2.80 ktex and the first and second drawing slivers are 3.20 ktex. The roving is 340 tex and is spun into 27-tex yarn. New small apparatus required for this change included a 1-m. cutting board for sliver, two direct reading balances for sizing sliver and roving directly in tex, and a ½-m. roving reel.

Future Developments

The spinning test described uses standard and modified equipment except for the miniature opener. Approximately 20 tests a day can be made using a ½-lb. sample. This is the limit of the present organization; to go beyond it would require considerable change. Development of spinning tests for smaller size samples is contingent upon the development of adequate sampling methods, a current problem in the breeding program.

TABLE I. Results of Tests Made on Yarn From Bobbins Within a Sample and Bobbins From Different Samples

Number	First 30, lb.	Second 30, lb.
1	113	113
2	112	111
3	116	113
4	113	111
5	110	108
6	113	111
7	111	109
8	113	110
9	113	111
10	111	110
11	111	111
12	113	112
13	111	110
14	115	110
15	111	111
16	113	112
17	109	111
18	111	112
19	113	111
20	112	110
Average	112	111
Differences between groups		1.7
Differences between samples		1.9

Experiments are now being conducted on two new spinning tests. One requires a sample size of 50 g. which is processed on greatly modified standard machinery without the use of sliver except as finisher drawing. Spinning is done on a direct sliver-to-yarn frame at drafts in excess of 125. The small skeins are the same as those used in the ½-lb. test. Single strand breaks are also being studied for use in this test.

The second test requires a sample size of only 8 g. of cotton and no conventional equipment is used. The test consists of preparing, from the lint cotton, a simulated yarn whose strength correlates with the strength of yarn spun in the regular way.

The object of these experiments is to develop a spinning test that will adequately evaluate breeding material for yarn strength and at the same time make it economically feasible to test large populations.

Acknowledgments

The authors wish to acknowledge the many helpful comments and advice of Dr. H. D. Barker, Chief of Branch, in the development of the spinning tests, the able assistance of Mr. Herbert Hutchens, Cotton Technologist, whose long experience in cotton proc-

essing work has been invaluable in setting up these tests, and to express their appreciation to the staff members of the Knoxville Spinning Laboratory.

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Blending Cottons Differing Widely in Maturity

Part I: Effect on Properties of Single Yarns[1]

Louis A. Fiori, Gain L. Louis, and Jack E. Sands

Southern Regional Research Laboratory,[2] New Orleans, Louisiana

Abstract

The blending of extremely fine and coarse cottons was investigated as a possible way of economically using these difficult-to-market cottons in the blended form. Two cottons differing appreciably in fiber fineness (approximately 3.0 and 6.0 μg./in.) but having other pertinent fiber properties about equal were blended together to produce a mixture averaging about 4.0 μg./in. in fineness. For comparative purposes a control cotton also averaging about 4.0 μg./in. in fineness was used. The blended and control cottons were spun into coarse and medium yarns of varying twists and into yarn numbers suitable for weaving Type 128 sheeting (64 × 64). The spinning efficiency of the two cottons was evaluated, on a pilot plant basis, in terms of ends down per thousand spindle hours.

Waste, nep count, yarn properties (skein and single strand strength, break elongation, uniformity, and grade), and end breakage rate in spinning were similar for the blended and control cottons. Microscopical examination of yarn cross sections did not reveal any migratory tendencies of either the fine or coarse fibers. For the same yarn number the blended and control cottons produced yarns of similar diameters and softness values.

Introduction

The physical properties of cotton fibers fluctuate with and are dependent on environment, weather, variety, and preparatory treatments such as harvesting and ginning. As a result, important physical properties such as fiber length, fineness, strength, and grade vary considerably within crops and among crop years [19, 28]. Textile manufacturers, therefore, have had available only limited supplies of premium qualities and were forced from the very beginning of the industry to blend fibers differing in quality.

Up to about a decade ago manufacturers used only length and grade as criteria for blending cottons. Now, on the basis of available information on fiber fineness [7, 10, 11, 13, 16, 17, 21, 22, 23], manufacturers are recognizing this property as probably one of the most important fiber properties to consider in relation to quality and processing efficiency. Testimonial to the importance of fiber fineness is a trading regulation inaugurated in 1955 whereby the

[1] Presented at the Cotton Research Clinic, May 13, 1959.

[2] One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, New Orleans, Louisiana.

New York and New Orleans Cotton Exchanges incorporated a measure of fineness (lower limits 3.5 Micronaire Reading) as another quality criterion for transacting futures contracts [1]. As a result, manufacturers are including this property as an additional quality criterion for blending purposes. However, fineness values used in a blend usually have been limited to a small range around an average fineness. Average values of about 3.5–5.0 μg/in. are usually used in blends. This practice makes the fine (below 3.0 μg/in.) and coarse (above 5.0 μg/in.) cottons extremely difficult to market. A further complicating factor affecting their marketability is that when processed alone fine cottons, normally referred to in the trade as "immature," and coarse cottons are known to affect adversely yarn appearance and strength, respectively. As a result, immature cottons are discounted on an average of five dollars per bale depending on degree of immaturity and grade. This creates for the cotton merchant and farmer a continuing problem of disposing of these types of cottons. Since the supply of cotton of desirable fineness is limited, many mills must of necessity utilize available immature and coarse cottons in blended form without benefit of scientific information necessary to predict the processing performance of the resultant blends.

It has been postulated by Wood [30] and shown by Dunkerley [8] in a study of blends of Egyptian cottons that the properties of a blend can be predicted from the properties of the component fibers. Williams and Towery [29] reported the feasibility of blending wide ranges in cotton quality in spinning coarse-to-medium yarn numbers. O'Kelly [19], in a study where the seed of two varieties was thoroughly mixed before planting, concluded that the spinning efficiency of a variety was affected very little by the addition of a small percentage of lint of a variety with widely different fiber properties. In a study based on small scale processing in which six cotton varieties of contrasting fiber properties were mixed, Simpson [24] reported the possibility of an apparent acceptance of wide genetic variability because of adequate uniformity of the resultant blends. Little [15] indicated that field damaged cotton can be spun successfully by blending it with low Micronaire Reading cotton. Recently and mostly based on studies with man-made fibers, attempts have been made to explain the migratory characteristics of fibers differing in diameter or fineness when blended and processed into yarns, but literature references are contradictory and fragmentary. Nuding [18] stated that the finer fibers tend to migrate during spinning to the core of the yarn, leaving the coarser fibers on the surface. Lund [16] said that the shorter, thicker fibers tend to appear on the outside of the yarn; Morton in the same paper in discussing these findings postulated that with all other things being equal the inside of yarns would tend to be occupied by the fibers with greater thickness and greater length. Fiber fineness has been reported by Kennamer [12] to affect the diameter of yarns and consequently fabric width during weaving and finishing. No information is available, however, on the effects that blending fine and coarse fibers have on these same weaving and finishing properties and yarn diameters. In another study by Pfeiffenberger [22], problems of merchandising immature cottons are discussed with a suggestion that ways be found of blending this type of cotton advantageously. No scientific basis of blending these immature cottons is given, however.

Although literature on blending fibers of contrasting fiber properties is accumulating, most of it is limited in scope through use of small samples and processing performance evaluations only through the yarn stage. Information on blending cottons differing widely in fineness is meager, and success of such blends is still dependent on trial and error methods. It is becoming increasingly imperative that blends be used due to shortages of the more desirable qualities of cotton. This study provides a basis for the scientific blending of cottons differing widely in fineness as a step in utilizing more efficiently present difficult-to-merchandise cottons. This report discusses data through single yarns.

Materials and Methods

The purpose of this study was to compare the processing behavior of a cotton mixture composed of a blend of very fine and coarse fibers with that of an unmixed cotton sample of about the same average fineness (control). This was accomplished by blending 60% of the fine (3.0 Micronaire Reading) with 40% of coarse (6.0 Micronaire Reading) cottons, resulting in an average Micronaire Reading of 4.0 [11]. The processing performance of this blended sample was then compared with that of the control cotton whose Micronaire Reading was also 4.0. Throughout this experiment in tables and charts the

TABLE I. Fiber Property Summary *

Fiber property	Cottons			
	Control (4.0)	Blend (4.0)	Fine (3.0)†	Coarse (6.0)†
Grade:	M	—	SM	M
Length:				
Classer, in.	1	—	1	1
Fibrograph				
UHML, in.	0.95	0.98	1.02	0.99
ML, in.	0.75	0.77	0.76	0.82
UR	79	79	75	83
Fineness:				
Micronaire reading	4.0	4.1	3.2	6.2
Maturity:				
Sodium hydroxide method, %	69	69	58	92
Strength:				
Stelometer ⅛ in. gauge, g./tex	17.8	18.3	17.8	19.2
Elongation:				
Stelometer ⅛ in. gauge, %	7.9	8.5	7.5	8.2

* Measurements made on picker laps.
† Blended to form the blended (4.0) cotton.

blended sample is referred to as blend (4.0), the control unblended sample as control (4.0), and the fine and coarse cottons used to produce the blended cotton as fine (3.0) and coarse (6.0) respectively.

Samples

Three cottons having essentially equal fiber properties except fiber fineness were used. The control, a cotton of average fineness (4.0 Micronaire Reading), and one experimental cotton, a fine relatively immature variety (3.0 Micronaire Reading), were obtained from an area in Mississippi known to grow Deltapine. The second experimental cotton, a coarse (6.0 Micronaire Reading) Rowden variety, was obtained from Arkansas.

Blending Procedure

Each bale of cotton was thoroughly blended to insure a homogeneous mass of cotton for each fineness level. The blend of fine and coarse fibers was made at the picker by properly proportioning the weights of the fine and coarse cottons in the form of breaker laps. Four breaker laps were then blended to form finisher laps. This blending technique assured that the evaluations would be based solely on the properties of the blend rather than partly on the blending technique.

Table I shows a summary of pertinent fiber properties measured on samples of finisher lap for all of the cottons used in this study. Picker lap data form a common basis of comparison for the blended and control cottons, since the properties of the former could be measured only in this form. The data show that for all practical purposes the control and blended cottons are very similar in fiber properties, particularly the fineness values. Even though there is a difference in grade between the fine (Strict Middling) and coarse (Middling) cottons, blending the two together should yield a cotton mixture whose waste content should be close to that of the control cotton.

In general, fineness (estimated from air porosity measurements) and maturity are highly correlated in American Upland cottons, so that low Micronaire Reading is usually associated with "immaturity." Therefore, the cotton designated as "fine" in this study can also be considered as immature, as indicated from the data in Table I. Also, fiber fineness, as used in this paper, can be interpreted in terms of either Micronaire Reading or Weight Fineness (Suter-Webb).

Processing Procedure

About 30 lb. each of the fine, coarse, blended, and control cottons were processed alike on conventional processing equipment into three yarn numbers [14/1 (42 Tex), 21/1 (28 Tex), and 36/1 (16 Tex)] of varying twist multipliers (3.7–5.7 in increments of 0.5 twist multiplier).

These small lots were used to determine mainly the percentage of fine and coarse cotton needed to obtain a blend having a 4.0 Micronaire Reading and the reaction of the blend to spinning performance.

About 330 lb. each of the control and blended cottons were used in processing performance evaluations of nep formation, ends down in spinning, single yarn and fabric properties, and finishing behavior. These large lots were spun into a 21/1 (28 Tex) warp and 23/1 (26 Tex) filling and then woven into a Type 128 sheeting.

The procedure for processing both the small and large lots was as follows. The small and large lots of each cotton were carded at 9 lb./hr. Nep counts were made at the beginning (10 min. after starting), middle, and end (10 min. before finishing) of the

stripping cycle, using the North Carolina State method [3]. A total of 18 nep boards was used for each stripping cycle.

A large scale spinning ends down test was incorporated into this study during the spinning of the warp yarns. The following spinning specifications and conditions were used.

a. 216 spindle Whitin Casablanca.[3]

b. Ring diameter, 2½ in.; spindle r.p.m., 8450; traveler size (Victor) 2/0.[3]

c. Single creel roving.

d. Ends down were recorded and categorized.

e. The control and blended cottons were each divided into two complete roving creels. The control and blended creels occupied opposite sides of the frame. After four doffs, the control and blended rovings were switched to opposite sides of the frame for the remainder of the test.

f. Eight doffs were spun totaling about 4700 spindle hours.

g. Warp yarn size was 21/1 (28 Tex).

h. The twist multiplier was 4.5.

Filling yarns were spun under identical conditions as the warp on the same spinning frame, except with a twist multiplier of 3.6. End breakage was not recorded because of the limited number of spindle hours used.

This report gives the findings up to single yarns. Data on fabric properties will be published in another report.

Testing Procedure

Skein strength determinations were made on a pendulum-type tester of 0–150 lb. capacity [2a], and single strand strength and break elongation measurements were made on an automatic Uster single strand tester.[3] Fiber strength and elongation properties were measured on the Stelometer [20, 27], and all other fiber properties were determined by ASTM methods [2b] from samples of picker lap. Photomicrographs were made by using ASTM [2c] and Laboratory [6] methods. Yarn appearance grades were obtained by using ASTM methods [2a]. Yarn diameter and softness measurements were made by use of a new technique [25]. Impact strength tests were made on a Goodbrand Ballistic tester [3] [4] of 0–150 lb. capacity.

[3] Use of a company and/or product named by the Department does not imply approval or recommendation of the product to the exclusion of others which may also be suitable.

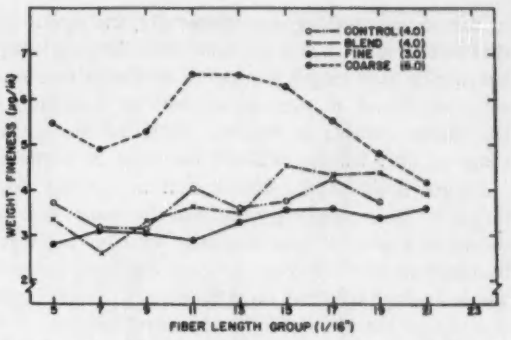

Fig. 1. Fiber fineness distributions of the control, blended, fine, and coarse cottons by fiber length groups.

Results and Discussion

The relative merits of the control and blended Micronaire Reading cottons were judged on the following quality and performance measures.

a. Fiber distribution comparisons of fineness and maturity properties.

b. Waste comparisons.

c. Nep formation comparisons.

d. Roving twist relationships.

e. Twist relationships to single yarn properties.

f. Ends down data based on large scale spinning tests.

g. Effect on single yarn properties of post spinning operations.

h. Effect on single yarn diameters and lateral deformation (softness).

i. Fiber migratory trends in single yarns.

Fiber Distribution Properties

Figure 1 shows the distribution of average fineness by fiber length groups for the control, blended, fine, and coarse cottons. It is evident that the distributions of fineness by fiber length groups for the blended and control cottons are similar. It appears that the fine and coarse cottons can be blended to produce a fineness distribution typical of that found in a normal unblended cotton such as the control. The fibers representing the extremes (2.75 µg./in. for the fine and 6.5 µg./in. for the coarse cottons) are still reflected in the average fineness of the blended cotton. However, on a single fiber basis it is probable that the extremes in fineness noted in this figure can be found in the unblended control cotton if examined on a fiber length group basis. Incidentally, these curves are fairly characteristic of commercial cottons

in this same length group. Generally, the figure indicates that short fibers are finer than the long ones, varying by fiber length groups. Curvilinear relationships are found, in some cases, such as was true of the coarse cotton; in isolated instances the entire range of fiber lengths is about the same in fineness.

Figure 2 shows the distribution of average maturity by fiber length groups for the same lots as shown in Figure 1. As was true for fiber fineness, blending the fine and coarse cottons produced a blend whose average maturity on a fiber length group basis was similar for the blended and control cottons. As with fineness, the maturity of cotton fibers in this case appears to vary with length, with the short fibers being less mature. It is also known, however, that in certain cases fibers of all length groups are of equal maturity.

Waste Content

Table II, comparing waste resulting from the picking and carding processes, shows about equal total waste content for the control and blended cottons.

Nep Formation

Figure 3 shows the nep formation data obtained during the carding of the control, blended, fine, and coarse cottons. For all practical purposes the blended and control cottons are very similar in nep content. Thus it appears that when a coarse cotton of low nep potential is blended with a fine one of high nep potential, a nep content value between the two nep levels can be expected [24].

TABLE II. Picking and Carding Waste (%) for the Blended and Control Cottons

Process	Cottons	
	Control (4.0)	Blend (4.0)
Breaker picker*	0.74	0.48
Finisher picker*	0.41	0.19
Card		
Flat strips	2.66	2.90
Cylinder and doffer strips	0.59	0.78
Motes and fly	1.30	1.19
Sweepings	0.22	0.24
Invisible loss	0.49	0.67
Total on card*	5.26	5.80
Total picking and carding†	5.93	5.99

* Based on difference between amount fed and amount delivered at each machine.

† Based on difference between amount fed at breaker picker and amount delivered at card.

The erratic nep increase as a function of the stripping cycle makes comparisons of nep content based on small samples and on selected portions of the cycle extremely hazardous. For example, nep content for the fine cotton at the beginning of the stripping cycle is about at the same level as for the control cotton, whereas at the end of the cycle the expected differences in nep formation are evident.

Figure 4 shows the extent of nep formation in the control, blended, fine, and coarse cottons and variations among eight stripping cycles resulting from carding approximately 330 lb. of cotton. Comparisons based on average neps per grain indicate that for either the beginning, middle, or end of the stripping cycles the card webs of the blended and control cottons had essentially the same nep content. This result substantiates conclusions for small scale processing (Figure 3). The average neps per grain followed an increasing rate of nep formation within stripping cycles much better than did the small scale processing evaluations. Analysis of the variation among stripping cycles for each measuring interval (beginning, middle, and end) reveals that the blended cotton had a coefficient of variation of 12.3% and the control cotton a coefficient of 17.60% for nep measurements taken at the beginning of each of eight stripping cycles. Variability increases for both lots to about 22% on measurements taken at the end of the same stripping cycles indicating that nep data become more variable with progress into the stripping cycle. This illustrates the risks involved in utilizing one stripping cycle without benefit of replication, since the results obtained sometimes are not repre-

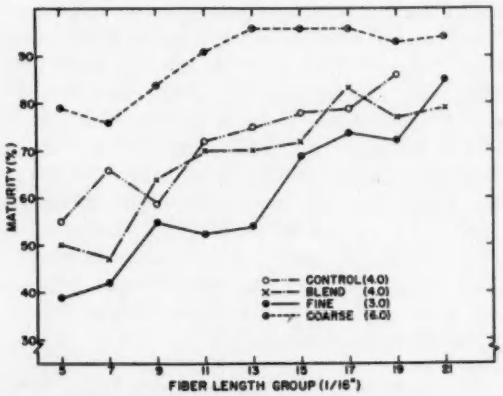

Fig. 2. Fiber maturity distributions of the control, blended, fine, and coarse cottons by fiber length groups.

TABLE III. Effect of Blending Cottons Differing in Fineness on Roving Twist

Cotton	Twist multiplier	
	30 lb.	330 lb.
Control (4.0)	1.00	1.09
Blend (4.0)	1.06	1.09
Fine (3.0)	.95	—
Coarse (6.0)	1.16	—

sentative. For example, for the fifth cycle of the control and the second of the blended cotton, there is little difference in the concentration of neps from the beginning to the end of the stripping cycles, and an erroneous conclusion could be made that there is no increase in nep formation as a function of stripping interval. This, of course, is in contradiction to the generally accepted carding concept.

Roving Twist

Since the fineness of the fiber influences the amount of twist to use for efficient drafting [5], particular attention was given the reaction to twist of the blended and control cottons. The data in Table III indicate that about the same twist is required for the blended and control cottons for both the small and large lots. Obviously, average fineness rather than the extremes in fineness is the determining factor for proper roving twist.

Single Yarn Twist Relationships

Strength. Figure 5 shows skein count strength product plotted as a function of twist for coarse and medium yarns spun from the control, blended, fine, and coarse cottons. The twist–strength curves for yarns spun from the blended and control cottons are similar in all respects. It is of particular importance that the same twist is required to obtain maximum strength in both yarns, even though yarns made from the blended cotton contain fibers varying extremely in fineness. It is apparent that the low yarn strength resulting from use of coarse fibers is offset by addition of the fine fibers. These conclusions are true for all of the yarn numbers evaluated.

Figure 6 presents a plot similar to Figure 5, except that it is based on single strand strength. For all practical purposes the observations made for skein strength hold true for single strand strength. It is interesting that in both cases the strength of the yarns spun from the blended and control cottons approached that of the yarns made from the fine cotton for the 36/1 yarns at high twists.

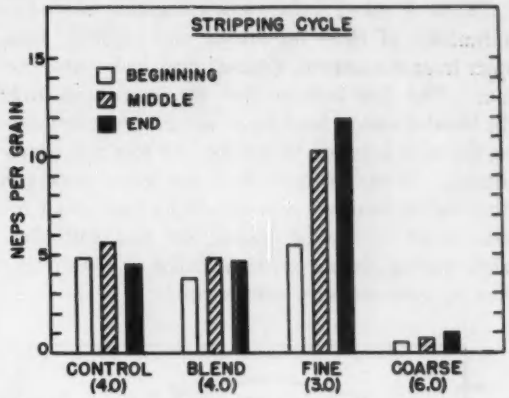

Fig. 3. Nep formation of the control, blended, fine, and coarse cottons (basis: 30 lb.).

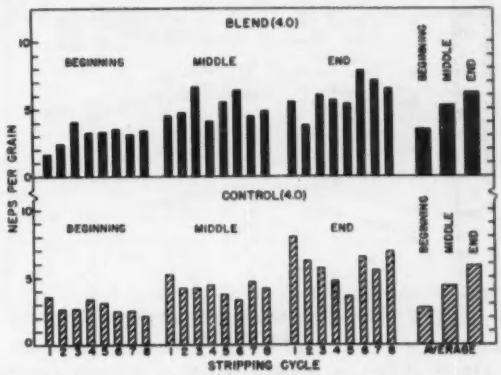

Fig. 4. Nep formation of the control and blended cottons (basis: 330 lb.).

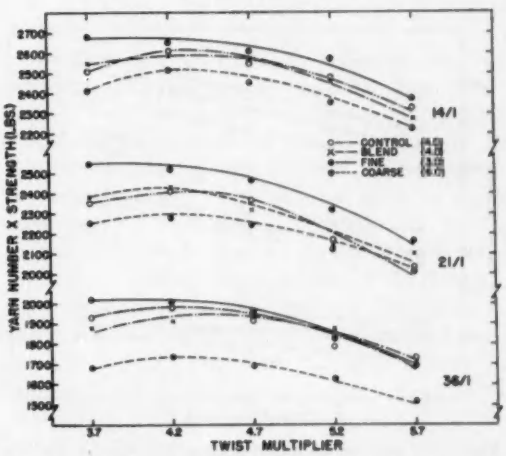

Fig. 5. Effect of blending cottons differing in fineness on skein strength of single yarns varying in twist (basis: 30 lb.).

Figure 7 shows yarn break elongation plotted as a function of twist for coarse and medium yarns spun from the control, blended, fine, and coarse cottons. The data indicate that the yarns spun from the blended cotton have break elongation values proportionately between values for the fine and coarse cottons. It is fortunate that the yarns produced from the blended and control cottons have about the same break elongation values, for this will allow fabric quality evaluations to be based on fiber rather than on yarn property differences.

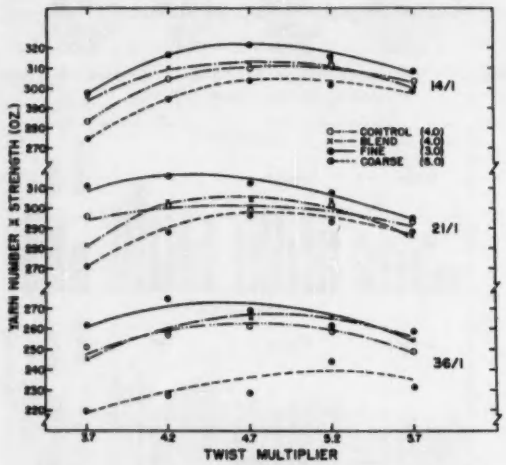

Fig. 6. Effect of blending cottons differing in fineness on single strand strength of single yarns varying in twist (basis: 30 lb.).

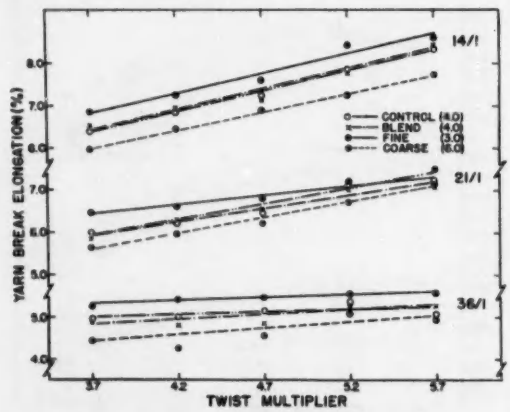

Fig. 7. Effect of blending cottons differing in fineness on break elongation of single yarns varying in twist (basis: 30 lb.).

Uniformity. The data plotted in Figure 8 show the effects of blending cottons differing in fineness on the uniformity of single yarns. Generally, the uniformity of yarns spun from the blended and control cottons is about the same for the 14/1 and 21/1 yarns of all twists. For the 36/1 yarns and with all twists the yarns spun from the control cotton were more uniform than those spun from the blended cotton. This tendency may be partially explained by the presence of coarse fibers in the blended cotton, which caused it to approach spinning limits more rapidly than the control cotton.

Impact properties. The effect of blending cottons differing in fineness on impact strength is shown by Table IV. The data indicate minor differences in impact strength for the 14/1 and 21/1 yarns spun from the control and blended cottons. Impact strength was somewhat lower for yarns spun from the blended than the control cottons for the 36/1 yarns at both twist levels. These differences measured statistically were significant at the 99% probability level. It is noted as a matter of interest that when the impact values of the fine and coarse cottons are averaged, these values correspond closely to those of the blend.

Yarn grade. Table V shows yarn grade comparisons for the control, blended, fine, and coarse cottons. Grades for all yarns spun from the blended and control cottons were about equal. The detrimental effects of the fine immature fibers apparently are offset by the coarse mature fibers, thus resulting in yarns of satisfactory quality.

Ends down in spinning. Figure 9 shows the relationship between cumulative ends down in spinning and doffs for the yarns spun from the blended and control cottons. The data are based on total end

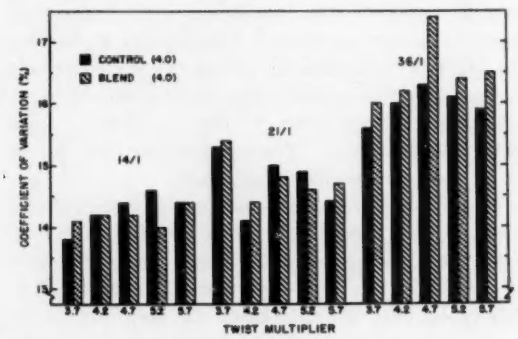

Fig. 8. Effect of blending cottons differing in fineness on the uniformity of single yarns varying in twist (basis 30 lb.).

TABLE IV. Effect of Blending Cottons Differing in Fineness on Impact Properties

Yarn	Cotton			
	Control (4.0), in.-lbs.	Blend (4.0), in.-lbs.	Fine (3.0), in.-lbs.	Coarse (6.0), in.-lbs.
14/1 (42 Tex)				
4.20 T.M.	49.0	50.5	54.1	45.3
4.70 T.M.	53.4	53.8	56.9	48.4
5.20 T.M.	55.6	55.4	60.6	50.0
21/1 (28 Tex)				
4.20 T.M.	46.55	45.50	48.20	43.15
4.70 T.M.	48.00	47.50	49.50	43.80
5.20 T.M.	48.80	47.75	50.70	45.40
36/1 (16 Tex)				
4.20 T.M.	44.10	40.98	43.30	38.52
4.70 T.M.	—	—	—	—
5.20 T.M.	44.52	41.95	44.82	40.22

breakage including slubs, roving breaks, and unknown causes. As expected with data of this type [26], a majority of the end breaks are categorized as being of unknown origin.

Generally, yarns produced from the blended cotton spun with fewer ends down than did those from the control cotton. After eight doffs there was a difference of ten ends down in favor of the latter cotton. However, measurement by use of chi-square indicated that the difference noted is not significant at the 95% probability level.

An interesting observation is the lack of end breakage during the first four doffs of the yarns spun from the blended cotton. Only 3 ends out of a total of 23 broke during over 2000 spindle hours of spinning. This happens quite frequently in data of this type and emphasizes the need for sufficient number of spindle hours to be used in order to insure valid results. Due to the closely controlled nature of experimental tests conducted in textile laboratories, the total number of end breakages occurring is extremely small, even after 5000 spindle hours, particularly as in this case where the spinning limits of the cottons were not approached. To increase the number of ends down numerically it would be necessary to spin to some predetermined number of end breaks—an approach which may be impractical due to the large number of spindle hours necessary. Other approaches may involve increased yarn tensions or spinning to progressively finer yarn numbers. A new approach using the latter technique has been developed [9] but was not yet available for use in this study.

TABLE V. Effect of Blending Cottons Differing in Fineness on the Grade of Single Yarns

Cotton	Yarn number		
	14/1 (42 Tex)	21/1 (28 Tex)	36/1 (16 Tex)
Control (4.0)	B+	B+	B
Blend (4.0)	A−	B+	B
Fine (3.0)	B	B	B−
Coarse (6.0)	A−	A−	B+

It should be remembered that the apparently equal spinning performance of yarns spun from the blended and control cottons was on the basis of a 21/1 yarn and warp twist. Performance when spinning finer yarn numbers might be in favor of the control cotton due to the inclusion of coarse fibers in the blended cotton.

Warp yarn properties. It is known that warp preparatory operations change the properties of yarns; Table VI presents warp yarn property comparisons of the blended and control cottons just prior to the weaving operation. These data represent physical properties of yarns from spinning through post-spinning operations, including the weaving, where warp yarns were subjected to normal loom operations without the insertion of the filling. It is evident that post-spinning operations affect each cotton alike, since the strength, uniformity, and elongation of yarns subjected to "loom rocking" are similar. Even the expected drop in yarn break elongation from the bobbin to loom state is about equal for the two comparative yarns. This is proof that the blended cotton in the yarn form can with-

stand the stresses of post-spinning operations equally as well as the control cotton in spite of the presence of extremely fine and coarse fibers. Since the two experimental yarns are equal in properties, a valid basis is provided for comparison of fabric quality. Differences noted in fabric quality should then be attributable to the properties of component fibers rather than the yarn properties, *per se*.

Yarn diameters. Since fiber fineness has been reported to affect the diameter of yarns [12], diameter and lateral deformation (softness) measurements were made on the warp and filling yarns spun from the blended and control cottons. Table VII shows the effects of blending fibers differing in fineness on yarn diameter and lateral deformation (softness). It is evident that the diameters of the two yarns being compared are similar and that when subjected to pressures of 12 lb./sq. in. lateral deformation properties are also equal. Apparently, the average fineness of component fibers in a yarn rather than extremes in fineness determines the diameter of yarns. Also, since the diameter of yarn influences greatly the contraction and dimensional stability of fabrics during weaving and finishing operations, it is expected that the blended and control cottons will perform similarly during these operations.

TABLE VI. Effect of Blending Cottons Differing in Fineness on Strength and Elongation of Single Yarns During Warp Preparatory Processes

Cotton	Strength: Count strength product	Strength: C.V., %‡	Elongation, %
	Bobbins*		
Control (4.0)	2204	5.6	—
Blended (4.0)	2198	5.4	—
	Bobbins†		
Control (4.0)	298	10.9	7.1
Blended (4.0)	299	10.9	7.1
	Cones†		
Control (4.0)	289	11.0	7.4
Blended (4.0)	296	10.7	7.4
	Unsized warp†		
Control (4.0)	289	8.9	6.8
Blended (4.0)	294	11.4	7.1
	Sized warp†		
Control (4.0)	299	10.7	5.2
Blended (4.0)	303	9.3	5.4
	Loom rocked†**		
Control (4.0)	299	11.8	5.6
Blended (4.0)	292	11.5	5.2

* Based on skein method and eight doffs, totaling about 4700 spindle hours.

† Based on single strand method and eight doffs, totaling about 4700 spindle hours.

‡ Coefficient of variation calculated by use of standard statistical techniques.

** Loom was "rocked" normally without insertion of filling.

TABLE VII. Effect of Blending Cottons Differing in Fineness on Yarn Diameter and Lateral Deformation (Softness)

Cotton	Unpressured diameter, cm.: Warp	Unpressured diameter, cm.: Filling	Softness* (% Increase): Warp	Softness* (% Increase): Filling
Control (4.0)	.025	.026	38.0	43.7
Blended (4.0)	.024	.026	38.9	45.4

* Softness values were calculated as percent increase in diameter [25].

Migratory characteristics. Figure 10 shows photomicrographs of the yarns produced from the control, blended, fine, and coarse cottons.

Cross-sectional properties of yarns spun from the fine and coarse cottons are illustrated by the photomicrographs in the lower portion of this figure. These two cottons, which are typical of fine and coarse cottons in general, are the component fibers of the yarn spun from the blended cotton shown in the photographs in the upper right-hand portion of the figure. A cursory examination of this figure reveals no real preferential migration of either the fine or coarse fibers. However, it might be speculated that this specimen shows a tendency for the coarse fibers to form a ring around the outer periphery of the yarns with the fine fibers as a core. It should be noted that sampling techniques for this type of analysis are extremely difficult and that work is required beyond the scope of this study to establish firmly the migrating properties of fine and coarse fibers.

Discussion of Results

The results of this study show promising possibilities for blending extremely fine and coarse American cottons to produce single yarns of acceptable quality, particularly where the spinning limits of a cotton are not approached too closely.

Similarity of the fiber fineness distribution by length groups of the blended and control cottons leads to the conclusion that these difficult-to-market cottons can be mixed together without appreciably altering the characteristic fineness distribution patterns found in normal unmixed cottons of average

fineness. It follows, therefore, that the processing performance, in terms of single yarns, of mixtures of cottons containing extremely fine and coarse fibers should be no different than that of cottons of average fineness which inherently contain fibers differing appreciably in fineness.

It appears feasible that a mill should be able to blend fine and coarse fibers with a cotton of average fiber fineness (4.5 μg./in.), producing a blend whose processing characteristics are no different than the unmixed cotton. Evidence of successful commercial blending of this type has been reported by Landstreet [14]. It should be cautioned, however, that wide variations in average fineness of a cotton mix may be expected when blending cottons of the type used in this study unless proper precautions are taken to insure a homogeneous mixture of the fibers through use of carefully controlled mixing procedures in the opening room.

Since coefficients of variation of fineness from a fiber length distribution of normal cotton are known to vary considerably, ranging from about 5 to over 11%, it can further be postulated that the mixing of two uniform fine and coarse cottons can actually result in a mixture of fibers whose average fineness properties within length groups are better than an unmixed cotton having a high coefficient of fineness variability.

Economically successful blending of fine and coarse fibers should help cotton competitively. Fine immature cottons are discounted depending on grade and degree of immaturity, so that their successful use in blends reduces the unit cost of the finished article. Also the supply of cottons of those finenesses (4–4.5 μg./in.) most in demand is limited by environmental factors. As a result, once the most desirable cotton qualities are depleted, mills have available only supplies of fine and coarse cottons and hesitate to utilize them to their fullest potential. In fact, some mills may even begin to use better quality and more expensive cotton to insure required performance standards. Because of hesitancy on the part of industry to use the fine and coarse cottons, farmers and merchants find it difficult to market these kinds of cottons. Successful blending of these types of

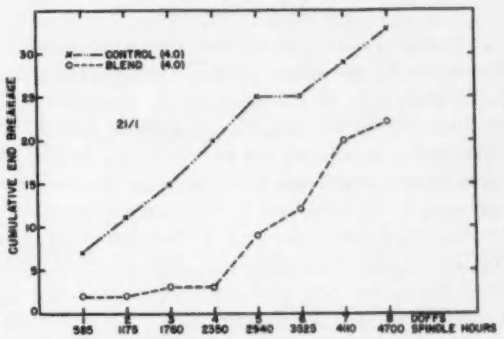

Fig. 9. Effect of blending cottons differing in fineness on end breakage in spinning (basis: 4700 spindle hours).

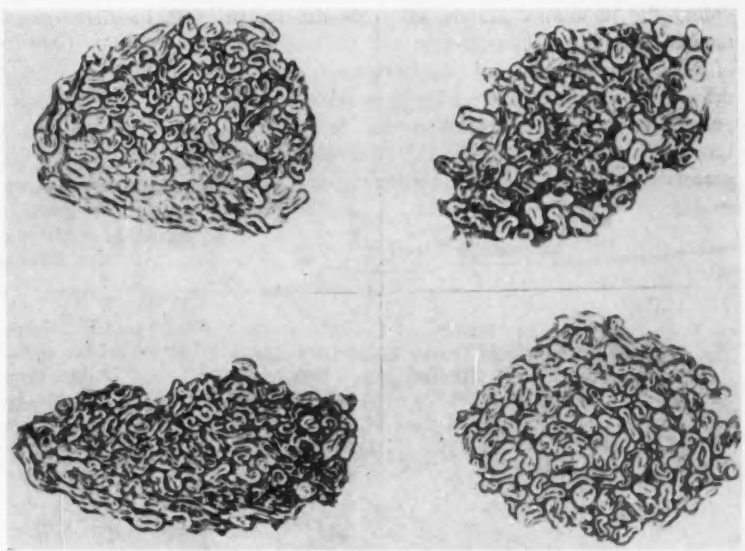

Fig. 10. Cross-sectional characteristics of single yarns spun from the blended and control cottons. From upper left: control (4.0), blend (4.0), fine (3.0), coarse (6.0).

cottons should result in an increase in their utilization and also more orderly distribution of sales by qualities throughout the marketing year.

The limitations of this study should be fully realized insofar as the comparisons between blended and control cottons are concerned, particularly since samples were limited to one bale and in thoroughly blended form to begin with. However, the production of yarns of good quality from a mixture of cottons differing appreciably in fiber fineness should, in itself, without any comparative data, stimulate the industry to perhaps consider more efficient means of blending cotton fibers through use of preblending techniques or radical redesigning of existing blending equipment.

Acknowledgment

The authors wish to express their appreciation to the following members of the Cotton Mechanical Laboratory: A. T. Callegan, C. J. Bouquet, S. J. Raffray, P. A. Varnado, R. J. Pertuit, and N. A. Bouquet for processing the cottons into yarns; E. A. Honold for supplying data on yarn diameter and softness; L. A. Leitz and A. V. Castillon for making the necessary calculations; S. M. Reinhardt for making uniformity measurements; and H. W. Little, Statistician, for help and guidance in pursuing the experiment and analyzing the data. Special thanks are also due to A. B. Cooper, D. C. Legendre, M. M. Smith, and W. F. McSherry for determining physical properties of fibers and yarns; I. deGruy for providing the photomicrographs, all from the Instrumentation and Analysis Group; and G. I. Pittman of the Engineering and Development Laboratory for drawing the charts. Special appreciation is also expressed to J. Leahy, Volkart Bros., New Orleans, La., for his help in locating the American cottons possessing the special fiber properties used in this study.

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Large Scale Commercial Blending[1]

Joel F. Hembree

Otto Goedecke, Inc., Hallettsville, Texas

BLENDING in our thinking has its basis in measurement and proportioning. A blend is made when different compatible components of known properties are comingled in such a way that their characteristics emerge as a new and reproducible product. On the other hand, a mix is made when the components are recognizable but more or less evenly diffused. Measurement and proportioning are not required for mixing. An illustration of this difference can be seen in Figure 1.

There is a chronology in the conditions that have brought about the need for blending. Let's consider the variation in the fibers inside a boll of cotton; see Figure 2. Note the variation among the different locations on the seed. This is only the beginning, as can be seen from data showing the variation in fiber properties of the cotton from a single stalk; Table I. Just as an aside, if we think of a bale of cotton as 500 lb. net weight and composed of fiber 1 in. long with a Micronaire of 4.5, the bale will contain 50,400,000,000 fibers, which is enough to make 70,000 tests. A comparison of the amount of variation in bales of raw cotton and blended cotton makes one appreciate the difference between blended cotton and its country cousin.

Analysis of fiber data developed in conjunction with the spinning tests conducted by the United States Department of Agriculture on selected varieties of cotton reveals only a small part of the variability characteristic of the cotton crop in any given years. These data are shown in Table II.

The extent of the variation balewise over an area with the same soil and presumably the same environmental conditions can be seen in Table III. The data for tensile strength and fineness in Table III are for 26 locations in the Rolling Plains of Texas for midseason cotton. Similar data are shown in Table IV for 10 locations in the El Paso area of Texas. Have you ever stopped to consider how many bales must be examined out of the Rolling Plains at midseason to find 100 bales of Middling White $\frac{15}{16}$-in. cotton falling inside the strength limits of 78,000 and 82,000 lb. and the range of 3.8–4.3 Micronaire units? The figure is about 800 bales. Blending is a basis for reducing this difficulty. Furthermore, it provides a way to eliminate many of the problems associated with bookkeeping pertaining to the stock with respect to the number of bales by quantity, qualities, and prices. The problem of how to store cotton for accessibility is simplified because all bales are alike. Consequently, opening room help cannot make a mistake and get the wrong cotton or feed it incorrectly.

So far our concern has been with bale-to-bale variability of the cotton in the crop. The variation inside a bale of cotton is equally important. Stability of raw material from unit to unit is one source

TABLE I. Average Micronaire, Tensile Strength, Length, and Variation in Fiber Properties on a Stalk of Cotton

Fiber property	Fiber data		
	Average	Range	St. dev.
Micronaire	3.5	2.2	.8
Tensile strength, lb.*	93.6	25.4	6.9
U.H.M. length	1.22	.14	.04

* × 1000.

TABLE II. Variation in Tensile Strength and Fineness Selected Varieties of Cotton used by United States Department of Agriculture in Spinning Tests— Crops of 1954–1958

Variety	Location	Standard deviation	
		Ten. str., lb.†	Micronaire
Lankart	Tex., Okla.	4.3	.46
Coker	Ala., Ga., N. C., S. C.	3.8	.35
Deltapine*	Tex., Okla.	3.9	.36
Northern Star	Tex., Okla.	4.5	.36
Acala 4–42	Calif., Ariz.	4.2	.28
Acala –44	Ariz., N. Mex.	3.7	.30
Acala 1517	Tex., N. Mex., Ariz.	3.3	.37
W. Stormproof	Tex., Okla.	3.3	.74
Deltapine 15	La., Miss., Tenn., Ark Mo.	3.1	.33

* TPSA and 15.
† × 1000.

[1] Presented at the 1959 Cotton Research Clinic, Asheville, N. C., May 13, 1959.

of efficient processing. Stability can be had in several ways, but when it is necessary to check each and every bale, as is the case with raw cotton, it becomes costly. Relatively few bales of blended need to be checked because the process by which they are made reduces internal variabilities of fiber properties. The difference can be seen in Figure 3. The components of the blended bales are the same, and environmentally induced differences are eliminated through the high degree of randomization of the fibers. Does the process used really blend, or perhaps I should say randomize? The answer is shown in Table V. The variance analysis was made on four measurements per bale on 80 bales of blended cotton. The bales were not all out of the same lot but were from different lots to give a better test of within bale stability. The analysis shows no significant difference among tests for tensile strength in the bale. Since the test for tensile strength shows no significant difference among measurements on the same bale, there is good

TABLE III. Tensile Strength and Fineness of Cotton from the Southern Part of the Rolling Plains, Midseason, Crop of 1958–1959
Data in %

Tensile strength, × 1000 lb.	Micronaire units *				
	3.5–3.9	4.0–4.4	4.5–4.9	5.0–5.4	Total
64– 66		.2	.2	.2	.6
67– 69		.5			.5
70– 72	.5	.5	2.0	.5	3.5
73– 75	.2	1.5	1.8	.2	3.7
76– 78	.8	2.6	4.1	1.8	9.3
79– 81	1.3	5.1	6.7	3.6	16.7
82– 84	.5	3.1	11.2	4.1	18.9
85– 87		4.1	8.2	5.6	17.9
88– 90	1.0	3.6	8.2	1.8	14.6
91– 93	.5	3.1	2.8	1.0	7.4
94– 96	.2	2.6	2.0	.5	5.3
97– 99	.2	.2	.8	.2	1.4
100–102		.2			.2
Total	5.2	27.3	48.0	19.5	100.0

* Pressure: 6 lb.
Source: Cotton Economic Research—The University of Texas.

TABLE IV. Tensile Strength and Fineness of Cotton Sampled from El Paso Area, Early Season—Crop of 1958–1959
Data in %

Tensile strength, × 1000 lb.	Micronaire units *				
	3.0–3.4	3.5–3.9	4.0–4.4	4.5–4.9	Total
70– 72		1.3	.6		1.9
73– 75		2.5	1.9		4.4
76– 78		3.8	1.3		5.1
79– 81		5.8	2.5	.6	8.9
82– 84	.6	7.5	8.2		16.3
85– 87	1.3	10.7	7.5		19.5
88– 90	.6	7.5	9.4	2.5	20.0
91– 93	.6	1.9	4.4	.6	7.5
94– 96		4.4	5.8	.6	10.8
97– 99		1.9	1.3		3.2
100–102		.6	.6		1.3
103–105		.6		.6	1.2
Total	3.1	48.5	43.5	4.9	100.0

* Pressure: 6 lb.
Source: Cotton Economic Research—The University of Texas.

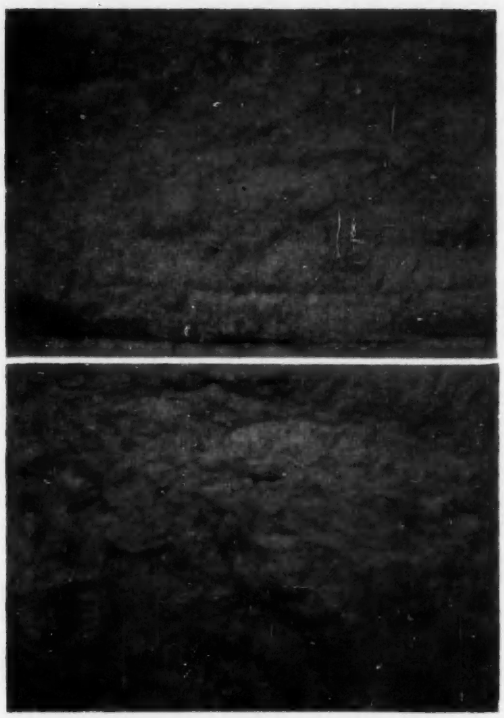

Fig. 1. Appearance of lap surface uniformity, blending compared with mixing. **Fig. 5.** Fiber randomization in blended and raw cotton.

TABLE V. Variance Analysis—Blended Cotton Tensile Strength

Item	Sum squared deviations	Degrees freedom	Variance	Variance ratio *F*	99% Value of *F*
Position in bale	7.15	3	2.38	.44	26.33
Bale to bale	45.21	19	2.38	.44	2.68
Discrepancy	310.22	57	5.44		
Total	362.58	79			

reason to expect the same is true with respect to other fiber properties. About 500 fibers are used in a test for tensile strength, while in the case of the Fibrograph the sample would contain some 200,000 fibers; the Micronaire sample would have about 700,000 fibers.

The difference in within bale variation found for raw bales by a disinterested research organization—Cotton Economic Research of the University of Texas—and results found on blended cotton by the laboratory of Otto Goedecke, Inc. on blended cotton belies the idea that blended cotton belongs to the same category as repacks, regins, and other irregular cotton.

One of the critical operations of a mill occurs in the opening and picking process. Comparison of blended and raw cotton at this stage reveals that the blended had less waste, as shown in Figure 4. The difference in the degree of fiber randomization in a picker lap made from blended cotton and one from raw cotton is shown in Figure 5. Note the splotches of color in the picker lap from the raw cotton and the uniformity of the distribution for the blended.

Waste in carding was substantially lower in the blended than in the raw cotton; this is evident in the data given in Figure 6. Associated with this is a reduction in fly in the card room. The nep count for the blended was not significantly different from that found for raw cotton where the same fiber properties were used. The number of ends down in spinning were substantially less for the blended than was true of the raw cotton, as can be seen in Figure 7.

While the relationship between yarn and final product is recognized, it seems fair to say that certain measures associated with processing up to and

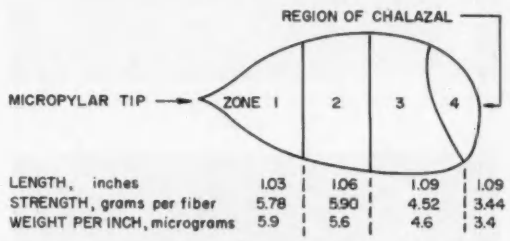

Fig. 2. Comparative length, tensile strength, and fineness of fiber on four parts of the cottonseed.

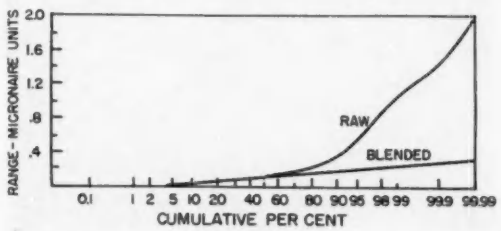

Fig. 3. Variation in Micronaire; blended and raw cotton.

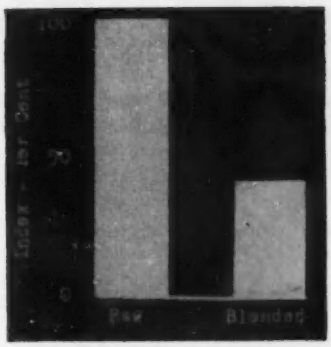

Fig. 4. Comparison of opening and picker waste.

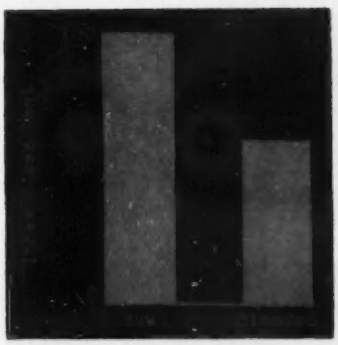

Fig. 6. Comparison of carding waste.

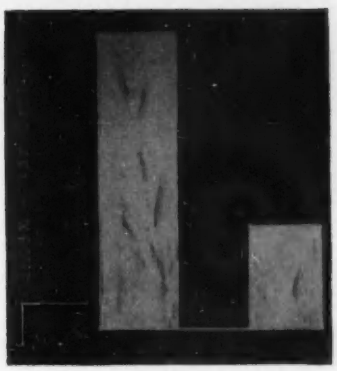

Fig. 7. Comparison of ends down.

through yarn may not carry through and their importance may be diminished in the fabric. Therefore, before such measures are used as a basis for approving or condemning a cotton, their importance in the final product should be known. Usually the baked cake tastes better than the dough from which it was made. A comparison of fabric made from blended and raw cotton is given in Figure 8. Observe the higher uniformity of the blended with respect to the color factor of yellowness shown in Table VI.

Another test that reveals the extent of randomization can be seen in yarn that has been differentially dyed. This is illustrated in Figure 9, which depicts the uniformity of dye distribution in raw and blended cotton. This is another way to illustrate the efficiency of blending and fiber randomization accomplished.

The interior of the blending plant at Brenham and one of the bales made therein are shown in Figures 10

TABLE VI. Comparison of Color in Fabrics Made from Raw and Blended Cotton

Kind of cotton	Reflectance		Degree of yellowness	
	Average	St. dev.	Average	St. dev.
Raw	50.40	.84	15.25	1.07
Blended	50.80	.73	14.09	.13

TABLE VII. Comparison of Blending Ratio for Raw and Preblended Cotton

Kind of cotton	Bales	Factor	Blending ratio
Raw	50	1	50
Blended	50	50	2500

Fig. 8. Fabric form; blended and raw cotton.

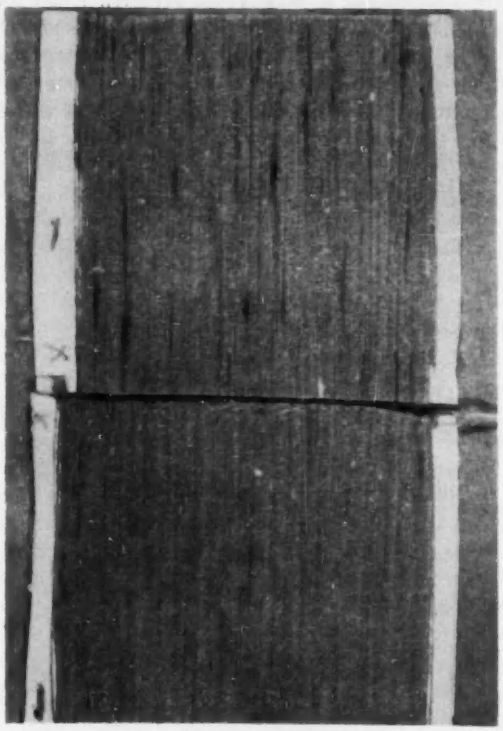

Fig. 9. Differentially dyed yarn from blended and raw cotton.

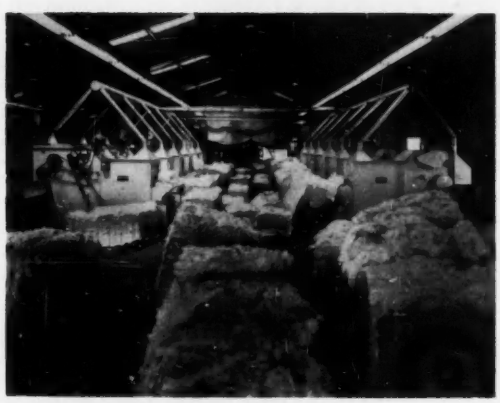

Fig. 10. Interior of blending plant.

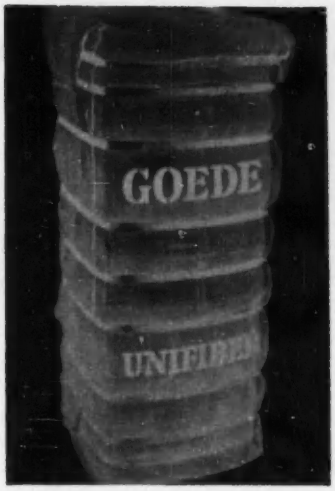

Fig. 11. Appearance of typical blended bale.

and 11. Note the neatness of the bale and the fact that it is completely covered. The bale is for practical purposes net weight because tare from bale to bale is the same. The bales will stack neatly and are easy to handle. There is no waste from the sample hole or contamination through it. Here truly is an ideal raw material and worthy of use for the following reasons.

1. Price and quality are equated in the blended cotton.

2. Desired fiber properties are brought together in the proportions required.

3. Recombination of measured fiber properties introduces a new dimension of uniformity through the interrelationship of fiber properties.

4. Intimacy of randomization in blended cotton assures uniformity of final product.

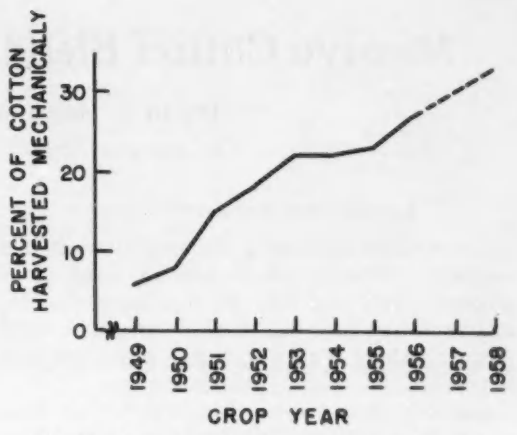

Fig. 12. Percent of American cotton crop harvested mechanically.

5. Carding machinery can do a more efficient job of cleaning when using blended cotton.

6. The record keeping and inventory problem is reduced.

7. Blended bales are completely packaged and for practical purpose net weight.

Two of the factors contributing to the necessity for blending are mechanical harvesting and ginning techniques. The trend toward mechanical harvesting is shown in Figure 12. Reliable sources estimate some 80% of the cotton is ginned in plants equipped with lint cleaners. The effects of any practices that detract in part from cotton's worthwhile properties should be largely eliminated if a high blending ratio is used. The blending ratio data for raw and preblended cotton are shown in Table VII; it is this development in quality control that marks another step forward in modern merchandising.

Massive Cotton Blending for Mill Production[1]

David E. Howe and Joe F. Mattison

The American Thread Company, New York, N. Y.

Introduction and Conclusions

Cotton's most challenging characteristic is its wild variability. We are able to measure many of its properties with precision; these measurements enable us to buy, mix, and process cotton into better yarns and fabrics at lower costs than would otherwise be possible.

However, these instruments cannot tell us when certain fiber properties are going to change, how many fibers or bales will change, nor how long this change will last. There are two principal solutions to this problem.

1. Mix according to specified design based on extensive testing.
2. Blend vast quantities of cotton to "level out" these variables.

We have attacked the problem by extensive testing and careful mixing, and have had satisfactory results for the most part, but at two of our mills we have now imposed a massive preblending program *in addition* to testing and "specification buying," and have had far more satisfactory results than ever existed before. We still maintain the strictest possible controls over buying, classing, testing, and mixing, but we also open 100 bales from various shippers' lots, blend these, rebale them, and follow our usual practices in the opening room later.

This has yielded a spectacular reduction in variable color of yarn, uniformity of fiber fineness is twice as good as before, ends down at spinning are appreciably lower and less variable, neppiness is lower and more stable, clearer waste has been reduced by 5–10%, and yarn strengths show less variation with the same breaking strengths as before.

There are four major questions which might well be answered in connection with this program.

1. Why preblend?
2. What should be preblended?
3. How should preblending be accomplished?
4. What are the results?

[1] Presented at Cotton Research Clinic, sponsored by the National Cotton Council of America at Asheville, North Carolina, May 13, 1959.

Why Preblend?

There is really nothing new in this idea at all. Earlier cotton manufacturers had blooming pits and blending rooms where bales were opened and allowed to "bloom"; small slabs were tossed around into one crib until a mountain of stock was assembled. As a matter of fact, the Egyptians and Sudanese still do this before the cotton is baled. Most of us, however, have found ourselves with no floor space for this kind of thing, labor costs have made it impossible to accomplish the "old-fashioned" ways, and we have sought scientific means of obtaining a homogeneous blend with a very small sample—20–40 bales per mix in the opening room. And yet, there is reason and evidence to believe that cotton is more variable as received today than it was in the past. Science, economics, and politics have all combined to add variability to cotton along with other advantageous changes. With science's improved and expanded breeding programs, new fertilizers, pesticides, and defoliants, and new methods of harvesting and ginning have come cottons with different dye indices and manufacturing indices (if there were such a thing), different chemical structures, varying degrees of fluorescence and, of course, some extraordinary properties of strength and fineness. Economics, too, has played a part in cotton's variability. The demand for high yielding strains of cotton, machine picking, and stepped-up ginning practices have put the spinner in a position where he is literally on guard at all times—frequently against an unidentifiable menace. Economics and government policies combined have created an artificial marketplace where demand and ultimate customer satisfaction do not shape the quality of the product nor its price. There are lengthy and learned treatises on the pros and cons of the government loan program—the fact is, though, that the loan has a most significant bearing on our raw material today.

Research literature in the cotton industry is unanimous in its advocacy of blending—no matter how it is to be done; examples are the other Clinic papers on the subject. Running through all this literature,

TABLE I. Fiber Properties from Original Bale Through Pickers

	Fiber length	Fiber strength			
		Zero gauge		⅛-in. Gauge	
	Upper 25% point in 32nds-in.	Pressley, lb./sq. in.	g./grex	g./grex	Fiber fineness, Micronaire
Original bales	36	87.633	4.38	2.21	4.65
Blending feeders	36	87.633	4.38	2.14	4.78
Preblended bale	36	87.833	4.39	2.13	4.73
Picker hopper	35	86.000	4.30	2.13	4.77
Picker lap	35	85.400	4.27	2.11	4.68

it seems to me, is both a confidence in our scientific skill in measuring the properties we want to blend and, at the same time, a tacit acknowledgment that we cannot really check all these properties and control them with consistent reliability. Mr. Guggenheim summarized this in his recent article "What's all this about Preblending" and he quoted one man—perhaps a skeptic—"If the steel industry didn't have any more control over its raw product than the textile industry, I would never go up in the Empire State Building again, because that rascal would be liable to fall down at any moment."

We recognized these variables as has everyone else, and we had only partly overcome them by careful selection and opening room mixes. We still found trouble in color and in physical yarn characteristics from four major areas.

1. Differences in bales within a given shipment.
2. Differences among shipments.
3. Differences in grades or varieties within a mix.
4. Differences from one crop year to the next.

These are the reasons we decided to go ahead on a major scale.

What Should Be Preblended?

The most obvious answer to that question is to preblend what you buy. And there is more to that than meets the eye. We specify Micronaire, territory, Pressley in many cases, color, and crop year, as well as the usual staple, grade, and character of our cottons. We also double check samples of incoming bales, but recognize that a crop will not make exactly what we expect, and we may have to spin it anyway. That means we must blend what we buy. Specifically, in our case, we blend according to Micronaire, we blend for color, and we blend across grades in certain instances. More than that, though, we blend across various shippers' lots, we blend to maintain the greatest continuity of mix minimizing abrupt raw stock changes and, of course, we blend very carefully from one crop year to the next.

TABLE II. Effect of Larger Opening Room Blends on Variation in Color—60/1 Combed Yarn
Opening Room Mix was Increased from 20 to 40 Bales per Mix in January 1958

Date	No. cones checked	Good cones	Streaked or defective cones	% Defective
Feb. 5	50	2	48	96
6	84	70	14	17
7	113	102	11	10
10	113	99	14	9
11	88	85	3	4
13	50	49	1	2
14	92	91	1	1
17	75	75	0	0
18	50	50	0	0
21	50	48	2	4
26	100	100	0	0

How Should Preblending Be Accomplished?

We first approached the blending problem by doubling and then tripling the number of bales in the opening room as being the most economical and flexible scheme. Tables II and III show that this reduced the incidence of color variation but did not correct it. We then opened, blended, and rebaled several lots of 100 bales each and followed these through the mill to find a spectacular reduction in color variation. This was the final test for us—we then went ahead on construction of our present set-up.

Figure 1 shows this layout, which comprises approximately 9,000 square feet. Ten new G-10 blending feeders made by Fiber Control Company of Gastonia are lined up back to back with five on each side. Fifty bales are laid down on each side

of the room to feed the 10 blending feeders. A Saco-Lowell feed table conveys the stock to an inclined apron which feeds an overhead rake distributor also made by Fiber Control. The rake distributes cotton to six Saco-Lowell F-5 hoppers which dump onto another Saco-Lowell feed table leading to an inclined apron loading a Murray double-box bale press.

In feeding the blenders our operator first makes a multi-bale sandwich which is fed to all five feeders on one side and then the five other feeders are loaded from bales on the opposite side of the room.

You will notice that there is no cleaning equipment whatever in this line at any point and the cotton receives an absolute minimum of handling. Bales are opened on the third shift, given a chance to bloom, and are blended on the first and second shifts. The blending feeders merely tumble the cotton onto the apron and strip it off with a Sargent comb. We have installed an automatic stop motion to arrest the entire line if the rake distributor finds all six F-5 hoppers are full. Thus, we do not recycle our stock. Actually, the equipment is timed so that this does not often occur anyway. The press operates on a 7-min. schedule which is just timed for convenient handling and removing of the other bale before rotating the entire assembly. Of course, the F-5's are automatically stopped while this rotation is being accomplished.

Since we have found our greatest variance to exist between lots of 100 bales rather than within lots, we have designed our 100-bale blends to contain a minimum of four distinct lots. This seemed reasonable since each lot might represent a different farm or territory and with these differences go all the variables described. Thus, at any given time, we maintain at least three lots in the warehouse with 25 bales in one lot and 50 and 75 in the others. Then, when a new lot of 100 bales arrives, we pull 25 bales from each of the four, thus maintaining our imbalanced stock of original bales.

Figure 2 shows this layout diagrammatically and demonstrates both the type of mixture we accom-

TABLE III. Effect of Larger Opening Room Blends on Variation in Color—60/2 Combed Yarn Opening Room Mix was Increased from 20 to 40 Bales per Mix in January 1958

Date	Blend	No. streaks per cone	No. cones	% Defective
Feb. 7	20-Bale mix	0	20	80
		1	10	
		2	18	
		3	24	
		Multiple	28	
Feb. 14	40-Bale mix	0	63	37
		1	19	
		2	5	
		3	2	
		Multiple	11	
Feb. 28	40-Bale mix	0	63	37
		1	12	
		2	4	
		3	5	
		Multiple	16	

TABLE IV. Effect of Preblending on Variation in Color—50/2 Combed Yarn

Date	Blend	No. streaks per cone	No. cones	% Defective
Feb. 7	Original bales	0	13	87
	20 per mix in	1	10	
	opening room	2	17	
		3	15	
		Multiple	46	
Feb. 14	100 Bales	0	99	1
	preblended	1	1	
	20 per mix in	2	0	
	opening room	3	0	
		Multiple	0	
Feb. 28	100 Bales	0	100	0
	preblended	1	0	
	20 per mix in	2	0	
	opening room	3	0	
		Multiple	0	

TABLE V. Effect of Preblending on Ends Down/1000 Spindle Hours—60/1 Combed Yarn 3.30 TM

Date	Frame no.	No. ends down	1000 Sp. hr.	Ends down/ 1000 Sp. hr.
		A. Cotton not preblended		
10/23/58	56	44	.888	41.667
	57	47	.810	58.025
	84	37	.888	73.198
	85	65	.888	49.550
		193	3.474	55.555
		B. Preblended cotton		
11/18/58	56	32	.884	36.823
	57	25	.816	30.637
	85	33	.850	38.823
11/21/58	56	61	.890	68.539
	57	38	.890	42.697
11/26/58	68	84	1.457	57.653
	69	27	.903	29.900
	72	31	.874	35.469
	73	92	1.639	56.132
		423	9.203	45.963

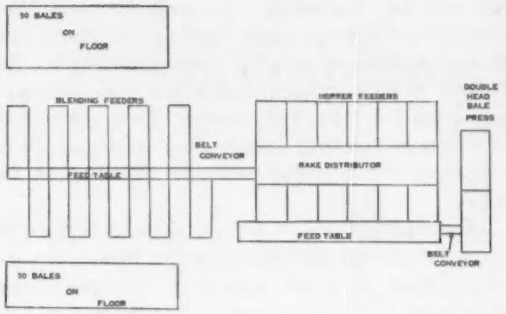

Fig. 1. Diagram of preblending equipment; American Thread Company's Clover Plants, Clover, South Carolina.

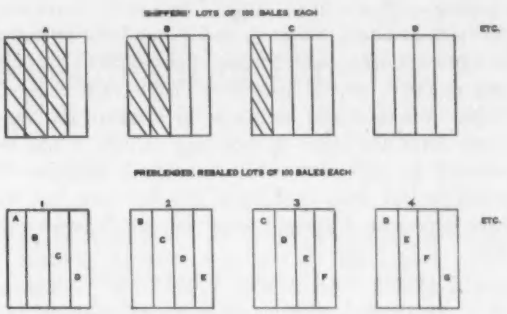

Fig. 2. Diagrammatic make-up of preblended lots.

plish and the continuity of raw material from the rebaled lots. We believe that an abrupt change, even with such preblending, would be very risky. Preblended bales are weighed, tagged, and stored for later use in the opening room, where we mix 20–40 bales—again drawing on a minimum of 4 preblended lots, each of which is readily identifiable as to its original make-up. The mathematics of our sample and our doubling is interesting—and also debatable. However, the minimum population represented in the opening room is 700 bales, as indicated in Figure 2 where we could conceivably draw our 20–40-bale mix from the 4 rebaled lots representing 7 shipper's lots A, B, C, D, E, F, and G. On the other hand, if more than 4 shipper's lots are represented at preblending and more than 4 rebaled lots are represented in the opening room, this "population" becomes very, very large.

We believe that this equipment, with our method of sampling, has given us a good degree of homogeneity, well opened cotton, and provides uniformly low density bales for the opening room with no rough treatment of fibers.

What Are the Results?

Since fiber fineness is one of the easiest as well as one of the most important properties to check, we made a study of variation in fineness within our picker laps. Figure 3 demonstrates that we have halved our coefficient of variation of Micronaire at the pickers—dropping it from 4.49% to 2.45% based on 100 laps of unblended stock versus 100 laps of preblended cotton. (Please notice this is a CV of Micronaire readings—*not* of yard to yard uniformity.)

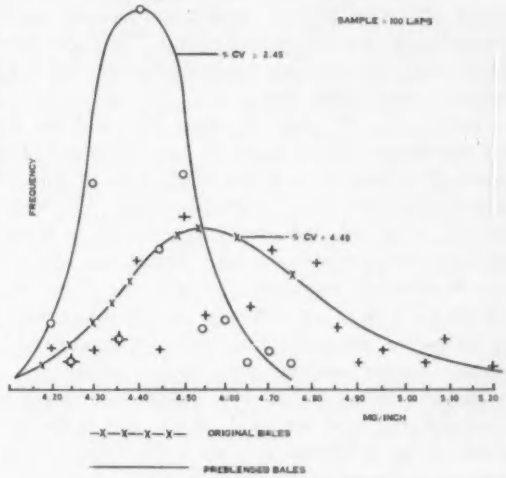

Fig. 3. Micronaire readings of picker laps. Sample = 100 laps.

Fibers have suffered no damage from this gentle opening, as indicated by Table I. We, of course, did not expect any change in fineness itself nor in fiber strength measured at zero gauge, and probably no change in strength measured at $\frac{1}{8}$-in. gauge, but we were interested in fiber lengths. Our tests have revealed no loss in fiber length. These data are further confirmed by our combers, which did not detect short staple; by ends down at spinning, which actually decreased; and especially by the amount of clearer waste, which we have measured to be 7% less on preblended cotton than on unblended stock, based on a study of 112 hr. spinning of a 30/1 where we creeled in roving from blended stock on one side and unblended on the other. Smaller tufts and uniform density have long been a goal in the

opening room and at carding. There is no doubt that we have attained this goal, and it has been reflected in more uniform feed from our opening room hoppers and in fewer reject laps—these have been reduced 13%. We have not been able to measure the very short term variation in our laps which would be affected by tuft size. Yard to yard variation is probably less dependent upon this tuft size, but we have experienced a slight improvement there—about 4%.

Nep counts were taken on production immediately before and shortly after we introduced this system. These counts showed a 12% reduction in neppiness, probably due to the more intimate fiber blend and also to the smaller tufts being more amenable to cleaning and carding. Thus, the finer fibers were dispersed and probably had less tendency to mass together into neps.

Tables II, III, and IV show our findings for fluorescent streaks on cones of yarn inspected after winding. These streaks had plagued us in spite of what appeared to be sufficient doubling. We found streaks at lap winding, drawing, spinning, winding, twisting and finished winding. Sometimes one end was fluorescent, sometimes several, and there was always the risk of a problem in dyeing, mercerizing, or worse—a streaked fabric on a customer complaint. Larger opening room blends helped, as is shown in Tables II and III, but we didn't really eliminate this until we went all the way with preblending, as is shown in Table IV. There have been virtually no problems with streaked yarns or streaky dyeing from this source since we adopted the preblending program.

Our spinning has been running better, and it has been much more stable. A limited test (Table V) shows a 20% reduction in ends down per thousand spindle hours on a 60/1. The absolute values before and after preblending are 55.555 and 45.963 respectively, but the comparison is more important, both because cycling has a bearing on the figures themselves and, of course, the twist on this yarn is low, making it a critical item at best. General observation definitely confirms a better spinning room with far less day to day variability.

Yarn strength has not been significantly affected on the average—nor did we look for it—but there has been less fluctuation from week to week. We follow these averages very carefully on charts and can see a narrower range in breaking strength. An analysis of yarn strength before and after preblending showed a 9.4% reduction in the coefficient of variation of breaking strength, but we expect there may have been a greater reduction than that on the whole.

In assessing these results, we have also tried to count the cost of this operation and reckon the net effect. First, of course, is the cost of equipment and the availability of floor space. As a matter of fact, we not only lacked floor space for this operation but were in serious need of more bale storage anyway. Thus, we felt our "out-of-pocket cost" should be the equipment itself. This totals $30,000. Our "out-of-pocket costs" of operating are 0.165¢/lb. of cotton processed, plus any overhead allocation used in individual mills. This cost might be called an incremental cost inasmuch as we added nothing but direct labor to handle this program. Offsetting this figure, small as it is, is the direct saving in spinning relative to ends down, which have been reduced about 20%. Other savings which cannot be measured as accurately, but which are probably more significant, include better cleaning, reduction or elimination of redyes, fewer rejects in our own mills, virtual elimination of color problems within our own mills and from customers, and the untold advantages in buying and storing of cotton within a crop year and even more so at a crop change.

Conclusion

Thus, we have been thoroughly satisfied that we are manufacturing a cleaner yarn more consistent in strength, color, appearance, and dye affinity at a lower cost than we ever did without the preblending. No one can really make a fiber any better than it is, nor can one change the crop, but we find that cotton bought under careful specifying, classing, and testing programs will stay closer to the mark if it is given massive preblending to get maximum yield from inevitably different fibers and to "level-out" characteristics which cannot be detected during full scale mill production.

The Continuous Flow Cleaning Line[1]

Louis Platt

Saco-Lowell Research & Development Center, Clemson, S. C.

OVER the past years, concern has been growing regarding the adequate cleaning and blooming of cotton in the opening room. During this time there has been a gradual deterioration in the standard of lap cleanliness and in some cases a marked increase in the curling or stringing of the processed stock.

Various reasons have been put forward for this decline, such as the mechanical picking of cotton, heating and precleaning at the gin resulting in an increase of pepper trash, as well as the old standby of lowering the grade standards. However, in the Council's publication "Cotton Processing Waste," August, 1958, a graph of the trash analysis of bales used in grade standards 1936–1956 shows that there has been little change in the actual trash percentage in the various grades. Allied with this is a downward trend for less total waste extracted during processing through the mill. This in itself shows that the machinery makers have been aware of this problem and during the last few years have increased the selective efficiency of their opening and cleaning machinery. However, it is apparent that the present standard of cleaning efficiency is still too low, and regardless of the above facts, there is definitely a deterioration in the cleanliness and opening of the lap cotton; somewhere along the line there must be a reason.

The state of the textile industry during the last years has become more competitive, both from internal and external sources. This has resulted in the advent of short-cut processing, higher production, and the lowering of the cotton mix, the latter point showing the way to the greatest saving in processing cost.

If we now look at the relationship of the opening and picking to the rest of the mill, it is more than likely we will find that the difference is as great as that between the Model "A" Ford and one of the 1959 automobiles. This process is sometimes reckoned as a necessary evil, and sometimes not even necessary, as happened at one mill which, when completed, was found to have no provision made for opening and picking machinery. This, of course, is a somewhat extreme example. However, let us consider a mill that was originally laid out for, say, 50,000 spindles. The opening and picking machines at the time were perfectly adequate for the job they had to do, at a probable production of 250 or 320 lb./hr./picker. Over a period of years modernization in the card room and spinning brought about increased efficiency and higher production; yet the opening and picking, with very little alteration, is now being asked to do just as good a job at 350–450 lb./hr./picker. But, as the production increased, efficiency in trash removal dropped, and complaints of dirty laps were made by the card room. The mill's answer to this was to put additional cleaning machines in the line to remove more trash, which was a generally accepted procedure. The result of this in cases where mills employed too many machines was overbeating, which caused degradation of the cotton staple, increase in neps, and curling of the cotton, all throwing additional work on the cards.

Of course, during this period high production machines which were more efficient in trash removal were designed and put on the market, but this was not the complete answer to the problem.

One of the most misunderstood machines has been the vertical opener, which properly used has been hailed as the finest cleaning machine evolved. However, when mills increased the work load on this machine to keep up with high production elsewhere in the plant, differences in the processed stock were apparent. If the draft through the machine was not increased, allowing the cotton to dwell, they found that they had created a condition which created neps and curled cotton not experienced in normal operation, while too great an increase in the draft reduced its effectiveness as a cleaner.

Misuse of the vertical opener, however, directed our attention to some of the fundamental principles

[1] Presented before the Cotton Research Clinic, National Cotton Council of America, Asheville, North Carolina, May 14, 1959.

involved in all present-day high production opening and cleaning machinery, and directed us toward a course of inquiry that would help our developments in the future.

The greatest saving in processing costs is the ability to drop the grade of the mix and still come up with an equal in finished product. Surely the best place to attain this is in the area of lowest capital cost per pound per hour of finished product—the opening and picking room.

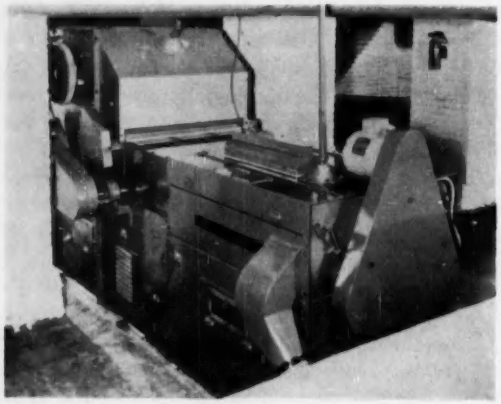

Fig. 1

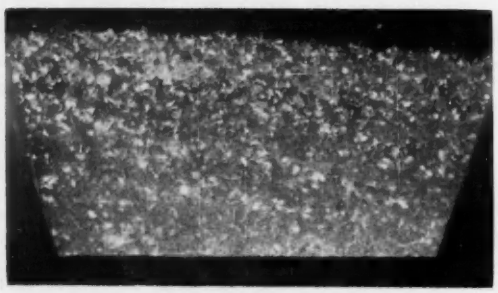

Fig. 2

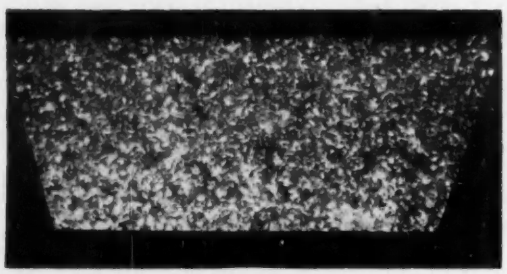

Fig. 3

It is for these reasons that we have approached the concept of an opening and cleaning line using a low production, high efficiency, flow line method; it is our belief that this method will process cotton with a higher cleaning efficiency, lower beater action and staple degradation, thus resulting in a cleaner, more even lap from the picker than has hitherto been possible. As yet, we are only part way along this line in what we can actually put on the market, namely the No. 15 Opener Cleaners, but in our own minds the way is clear, and we are now working toward the time when we can offer the new complete opening and picking line. It is the first part of this line, probably the most important part, that we wish to discuss.

The only machine of this line in production is the No. 15 Opener Cleaner, of which there are hundreds

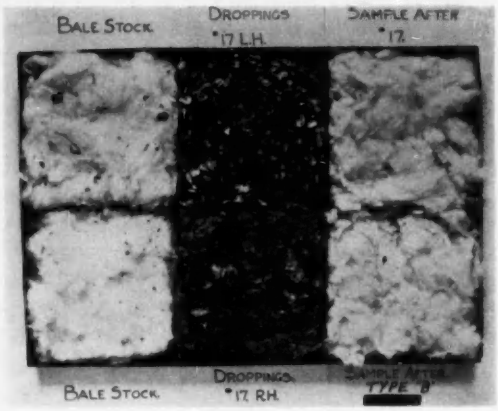

Fig. 4

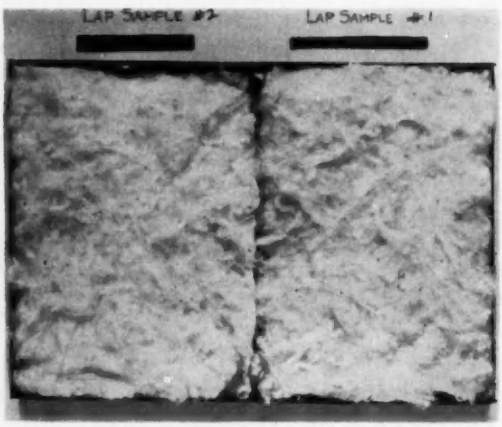

Fig. 5

in mills all over the world. This machine did such a good job that, recognizing the capabilities of cleaning and opening the cotton at low production, we designed another machine to follow in sequence; the No. 17 Opener Cleaner, which still is in only limited production. This machine has been tested under mill conditions; for the last year extensive tests have been made at various mills, and all tests have surpassed our expectations.

The machines under test have comprised the F7 Feeder, No. 15 Opener Cleaner, and No. 17 Opener Cleaner. These three machines were coupled together; their exterior appearance is that of one machine (Figure 1). The No. 15 is a Buckley beater and the No. 17 is a double pinned beater machine with exterior adjustable grid bar setting and each beater trash compartment separate and fulfilling a different function.

It has already been remarked that the percentage of trash in cottons has altered very little. What has altered is the general character of the trash, inasmuch as a greater percentage of the trash is now composed of leaf and grass and such trash that has a buoyancy equal, or nearly equal, to that of the cotton fiber itself. This, then, is the type of trash that is difficult to remove, and in processing breaks up into pepper trash and shows itself in the finished product. There is also a greater amount of small pieces of seed coating with long fibers attached, as well as immature seed with a great deal of fiber attached to them. This must be removed as soon as possible before any break-up occurs and makes the task of removal more difficult.

The first step necessary in efficient cleaning of cotton is to open the stock into as small pieces as possible, as gently as possible, without breaking up the trash particles. This can be done only in a free-feed type of opener; that is, a machine which does not hold the stock while it is being beaten. Therefore, the first machine in the line is the Blending Feeder, the feed lattice of which is combed with a high-speed oscillating comb. This feeds small pieces of stock to the next machine, the No. 15 Opener Cleaner, which again is a free-feed machine fitted with a Buckley Beater and having grid bars 216° of its circumference. Owing to the low production and small tufts fed, the cotton is gently agitated against the grids, all the cotton getting equal treatment and working, releasing motes and the larger trash particles and allowing them to fall through the grids. The stock is then free-fed directly into the No. 17 Opener Cleaner with its twin beaters, the pins of which are set spirally along their length, the beaters rotating in the same direction. On the upbeat side of the machine are a series of adjustable baffles which can be set from outside the machine. These can be positioned to either retard or accelerate the flow of stock, depending on whether more or less cleaning action is required. The draft through this machine is very low; the stock follows around the beater path and is not sucked through the machine without any processing. There is an induced air flow under the left-hand beater which assures that only motes and flakes and the larger trash particles can fall through the grids. Very little lint is found in these droppings. The trash compartment under the right-hand beater is sealed and separate from the left-hand side, and on this side the droppings consist mainly of the light pepper trash and fly. The difference can readily be seen in Figures 2 and 3, which show the interior of the trash compartments, and in Figures 4 and 5, which show representative samples. As can be seen, the droppings on the right-hand side are very similar in characteristic to those found in filter waste; again, there is a very small lint loss of actual spinnable fiber.

While there is very little difference as regards the principle of the No. 15 and the No. 17 Opener Cleaners with other types of beater cleaners, the higher efficiency of these machines is in the theory of low production high selectivity, in which all the stock gets equal treatment and is not forced through by the following stock.

Figure 6 shows the effect of increased production on these machines and proves that as production increases, cleaning efficiency of the machines drops.

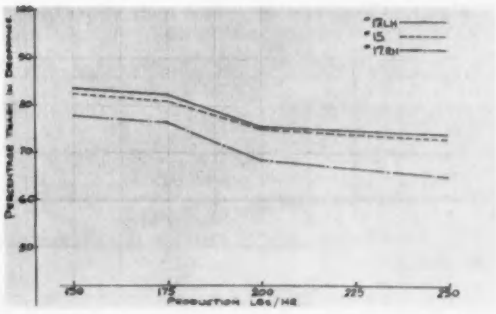

Fig. 6. Effect of increase in production on cleaning efficiency.

While the production is small the effect is seen; it occurs to a greater extent in high production machines when the production is increased from 900–1500 lb./hr.

The first mill trials on the prototype No. 17 Opener Cleaners showed that it was possible to eliminate at least two of the major cleaning machines in the line and still retain the same cleanliness of lap with a much better appearance of the stock. Table I shows the machinery set up and trash content of bale stock and finished lap, with different mixes. The regular line consisted of F7 Feeder—No. 15s—No. 16—No. 12—No. 12—two beater pickers. This line was used as the control.

While these results were encouraging, it was thought that we could still improve the F7—No. 15—No. 17 setup; further tests were carried out at Chicopee Manufacturing Corporation, Chicopee Falls, Mass., whom we wish to thank for their courtesy and cooperation.

The two previous installations at this mill were Feeders—vertical—two No. 12s—two beater pickers. One of the lines was altered by the inclusion of No. 15 and No. 17 Openers. The first test, on a 20-bale mix of L.M. and S.L.M. cotton, was to see the improvement in lap cleanliness on the modified line. Two 2,000-lb. lots were prepared and each was run through the respective lines. Table II shows the percentage of trash in the stock in each successive stage.

This test also showed that, even with the additional processing, the nep count on the card web was no higher.

Shortly after this test was completed, the mill altered its regular line by adding precleaners (Type A) to the feeders and by the further addition of a contemporary high production Opener Cleaner (Type B), the complete line being: Feeders—Type A Machine—Type B Machine—vertical—two No. 12s—two beater pickers. Over a period of time various comparative tests on the running mix were made on percentage of trash in the stock at various machines, also in the lap; the results are shown in Figure 7.

During the trial period we carried out extensive tests on the prototype No. 17 Opener Cleaner with

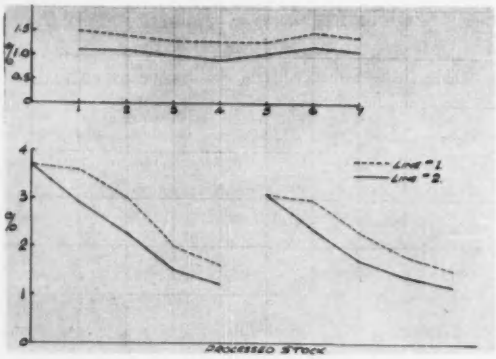

Fig. 7. Comparison of percent trash at various machines and in lap.

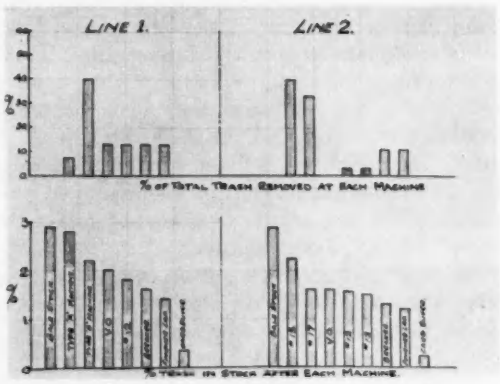

Fig. 8. Comparison of machine cleaning efficiency.

TABLE I

Test no.	Line layout	Lint, % Bale	Lint, % Lap	Trash, % Bale	Trash, % Lap	Loss, % Bale	Loss, % Lap
1	Regular line	95.88	98.27	1.94	0.72	2.18	1.01
1	F7—No. 15s—No. 17s—No. 16—2 Beater pickers	95.88	98.32	1.94	0.88	2.18	0.79
2	Regular line	95.75	98.19	2.39	0.90	1.86	1.00
2	F7—No. 15s—No. 17s—No. 12—2 Beater pickers	95.75	97.49	2.39	1.0	1.86	1.50
3	Regular line	96.76	98.50	2.72	0.89	0.52	0.61
3	F7—No. 15s—No. 17s—No. 12—2 Beater pickers	96.76	98.53	2.72	0.61	0.52	0.86

various beater speeds, grid setting, and flow of stock through the machine. Our findings showed that some alteration in design would improve the cleaning capacity of the machine. Therefore, the prototype machines were replaced with the new machines which incorporated the modifications we had found necessary. After a suitable running-in period we duplicated the previous large-scale test, the results of which have been analyzed only in the last month. These tests have shown a marked increase in the relative cleaning efficiency of the new No. 17 Opener Cleaner.

There is a difference in the machine sequence on the regular line, as previously remarked. This had been altered and was as follows: Feeders—Type A Machine—Type B Machine—vertical—No. 12—No. 12—two beater pickers. However, after this line had been running for a period, it was found that curling was taking place due to excessive beating. The last No. 12 Opener, being the easiest to bypass, was taken out of the sequence. This helped to a slight degree, but did not remove the initial cause of curling.

The next test was similar in all respects to the previous test: 20-bale mix of L.M. and S.L.M. cotton. Two 2,000-lb. lots were prepared and each run through the respective lines. Table III and Figure 8 show the percentage of trash in stock in each successive stage.

Table III is purely a summary of the test results and does not show the full advantages gained; for example, if we look at the trash content of the stock up to the vertical in both lines and compare it with the actual weight of droppings from each machine,

Fig. 9

TABLE II

	Regular		Modified	
Processing stage	Lint, %	Trash, %	Lint, %	Trash, %
Cotton mix	95.1	3.75	95.1	3.75
No. 15			96.2	3.1
No. 17			96.6	2.5
V.O.	95.8	3.4	96.5	2.4
1st No. 12	96.0	3.2	96.9	2.2
2nd No. 12	96.6	2.7	97.0	1.85
Breaker	96.6	2.4	97.3	1.6
Lap	97.3	2.05	97.3	1.3
Card sliver	98.9	0.42	99.2	0.26

TABLE III

No. 1 Line	Lint, %	Trash, %	No. 2 Line	Lint, %	Trash, %
Cotton mix	95.6	2.9	Cotton mix	95.6	2.9
Type "A"	95.6	2.8	No. 15	96.5	2.25
Type "B"	96.4	2.2	No. 17	96.5	1.6
Vertical	96.6	2.0	Vertical	96.5	1.6
1st No. 12	96.8	1.8	1st No. 12	96.5	1.55
2nd No. 12	—	—	2nd No. 12	96.6	1.5
Breaker	97.2	1.6	Breaker	97.3	1.3
Lap	97.7	1.4	Lap	97.9	1.1
Card sliver	98.5	0.32	Card sliver	99.0	0.23

TABLE IV

No. 1 Line	Trash, %	Accum. wt. of droppings, g.	No. 2 Line	Trash, %	Accum. wt. of droppings, g.
Feeders-Type "A" Machine	2.8	1490.0	Feeders—No. 15s	2.25	3491.4
Type "B" Machine	2.2	9413.9	No. 17s	1.6	8628.7

TABLE V

Position of sample	Line No. 1 Av. nep count/10 gr.	Line N. 2 Av. nep count/10 gr.
After Type "B" Machine	164	
After No. 17s		110
After V.O.	237	163
After 2nd No. 12		198

also the accumulative total, we find as shown in Table IV that the machinery in Line No. 2 is more selective.

A further analysis of the results shows that even with the additional machinery in Line No. 2, the total waste percentage at 2.45% is not much higher than Line No. 1, which is 2.11%. However, there is an appreciable difference in the percentage of trash extracted between the two lines: 48.2% in Line No. 1 and 62% in Line No. 2.

During the test, samples were taken from the delivery of several machines and a nep count was made. The results are shown in Table V.

When the results of the test were studied by the mill, it was generally agreed that for their particular mixture, from cleaning efficiency, nep count, and appearance of the stock, that the vertical and the two No. 12s were no longer required. This is not a condemnation of the vertical and the No. 12 Opener, which in their own right are efficient cleaning machines. However, in this case used after the low production, high efficiency No. 15—No. 17 sequence, the stock was overbeaten, a condition which would have prevailed regardless of the type of machine following. Figure 9 shows the mill installation.

These tests have confirmed our belief in the efficiency of a low production flow line. Here the stock is opened at the beginning, and progressively opened to the individual fiber if possible. There is no consolidation of the stock in the reserves or feeding systems until it reaches the reserve preceding the finisher section of the picker. At this point constant density and not volume will lead to a more regular and even lap.

This progressive opening process, with a minimum of beating, is essential. It is our hope that our experiments will succeed, enabling us to offer a complete opening and picking line using the flow line procedure, with a minimum of beaters, which will do an efficient selective cleaning operation with little fiber degradation, low nep count, and low waste loss. As previously stated, the No. 15 and No. 17 Openers, already designed and tested, make up the first part of this new line.

It may appear that with the greater number of low production machines the capital outlay would be higher. However, consideration must be given to the fact that the more expensive high production machines will be eliminated, so that a complete low production flow line will differ little in cost. A new installation would probably cost less than a conventional opening and picking line.

The advantages of a low production flow line are such that with similar lap production and low cost differential it is now possible to process a lower grade mix to a final cleaner, better-bloomed, less neppy picker lap.

Design of the SRRL Granular Card[1]

A. L. Miller and R. S. Brown

Southern Regional Research Laboratory,[2] New Orleans, Louisiana

Introduction

Investigations by the Southern Regional Research Laboratory of air pressure in the cotton carding machine [4] supported the theory that carding is a mechanical action. Further research efforts led to the conclusion that the essential requirement for carding is that the tufts and unopened groups of fibers deposited on the cylinder by the lickerin encounter a resistant force sufficient to separate the tufts without the removal of waste and spread the fibers over the entire area of the cylinder surface before reaching the doffer. Based on these principles, the SRRL Granular Card without revolving flats was developed, on which a progress report [5] was presented at the Cotton Clinic in February 1958.

Carding Apparatus

This new method of carding, which has been called granular carding, is such a radical change from that used for almost 200 years that a fairly extensive evaluation of the method was deemed advisable before releasing the development to industry. Evaluations were made first in the laboratory at New Orleans and then in a cooperating mill; a representative of the mill will report on their experience with the granular card in a separate paper.[3]

The new card was developed under a project aimed at reducing waste, while maintaining or improving quality, by accomplishing radical changes in the design of the machine. Changes in settings and speeds of the various components of the card in their conventional form were not included in the program, since this phase of work has been so capably handled by previous investigators. Certain basic studies of the standard card were made, however, to achieve a better understanding of its operation. Development and evaluation of the granular card has now progressed to a point where it is believed that appreciable savings in spinnable fiber can be realized while maintaining quality under most operating conditions.

The three main sources of waste in a conventional carding machine (Figure 1) are the flat strips, the cylinder strips, and the motes and fly, of which the flat strips comprise about 50% of the total. The granular card (Figure 2) produces no flat strips; hence the savings in waste. The design consists generally of an aluminum-oxide granular carding surface opposed to the surface of the main cylinder and a relatively small metallic wire clothed roll above the lickerin to preopen the tufts before carding. There is also recommended, but not essential, a modified lickerin and feed roll cover, to be described later, which improves the cleaning action of the mote knives through a reduction in the air pressure above the lickerin. The aluminum-oxide carding surface is fixed and rigid; it cards without loading and requires no attention during normal operation.

The SRRL granular card conversion complete with preopener roll and low-pressure lickerin cover is shown in Figure 3. The simplicity of the apparatus

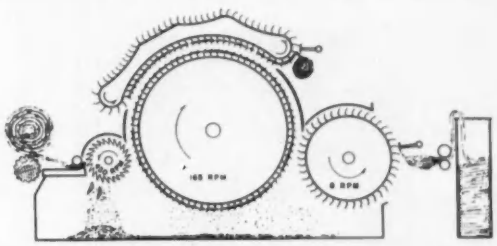

Fig. 1. Schematic sectional view of a revolving flat card.

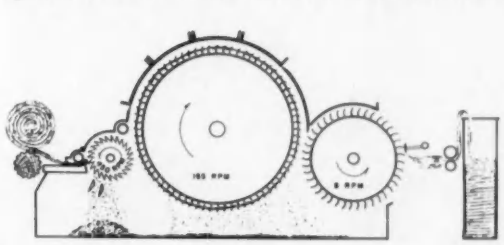

Fig. 2. Schematic sectional view of the SRRL granular card.

[1] Presented at the Cotton Research Clinic, May 14, 1959.

[2] One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

[3] G. P. Callaway; p. 737.

is evident from the smooth finish and lack of moving parts.

It is the policy of the Southern Laboratory to carry a development through to the point of proving it is practical and functional. The ultimate in design should be achieved by the manufacturers to suit their own methods of engineering and production. However, in the SRRL Granular Card Development, the design of the individual parts, the method of mounting and adjusting, and the economics of installing and servicing the apparatus have all been considered in order to achieve the same ruggedness for handling, sensitivity for adjusting, and longevity that is already associated with the textile card.

The largest single part of the apparatus is the granular top plate (Figure 4), of which there are four per machine, all identical and symmetrical end for end. The top plate is an aluminum alloy casting; the alloy has been specially selected for machineability and dimensional stability. Although the top plate is a rugged casting, it is vital that its surface be finished to the same tolerance as a flat bar, so that when it is installed on the card the clearance to the cylinder can be set to a minimum. Since the plate is structurally stable and rigidly mounted, settings of 0.005 in. are recommended and can be easily maintained. Experience has shown that the quality of the sliver improves with the closeness of the setting.

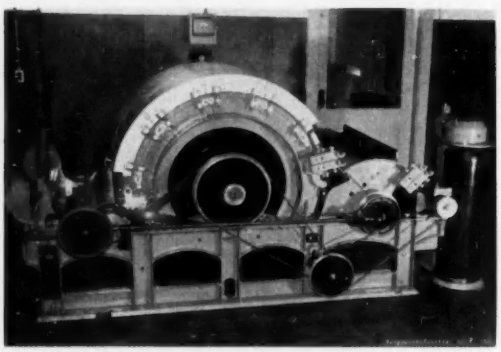

Fig. 3. SRRL granular card apparatus on a standard card.

Fig. 4. Granular top plate.

Successful performance of the Granular Card is dependent upon the setting of the top plates. Potential manufacturers of this apparatus are cautioned that machining of the 15 × 42 in. surfaces of each plate to the specified tolerances requires precision shop equipment and operator skill.

The granular surface on the plate is a coated fabric material with a pressure sensitive back which has been made available through the cooperation of the Minnesota Mining and Manufacturing Company, and is known as PSA 3-M-Ite Granular Card material.[4] As a carding surface this material has the very desirable quality of not loading with fibers and therefore requires no cleaning or attention whatsoever. Although the effect of granule size on nep count and yarn strength was found to be statistically significant, it will be noted from Table I that the differences are small within the recommended range of 60–100 granule size.

Installation of the 3-M-Ite material on the surface of the plates must be accurately controlled to prevent

[4] The mention of trade names does not imply their endorsement by the Department of Agriculture over similar products not mentioned.

TABLE I. Effect of Granule Size on Neps and Yarn Strength

	Granule size		
	60–80	80	100
Neps/grain			
After 5 lb.	5.3	5.0	4.1
After 15 lb.	6.1	5.0	4.8
After 25 lb.	6.6	6.6	5.0
Yarn strength*			
Skein (CSP)	2228	2223	2194
Single strand (CSP)	299	295	294

* Yarn number 28/1 (21.1 tex).

overlaps or air pockets, which will interefere with the setting of the plate to the main cylinder of the card. It is recommended that the material be applied with a rubber covered roll to prevent damaging the granular surface. It should be rolled onto the plate starting from one edge, being carefully rolled down as it contacts the plate to prevent air pockets or bulges (Figure 5). With a little practice a plate can be covered in less than 10 min. When the material becomes worn it is removed from the plate by lifting one corner with a knife blade and pulling off. The plate is left clean and ready for another application of granular material.

The plates are mounted on side brackets (Figure 6) designed to permit rapid adjustment. Subsequent removal and replacement of the plates can be made without fear of disturbing the setting.

The small metallic roll above the lickerin, which is referred to as a preopener roll because of its function of opening the tufts prior to carding, is shown in Figure 7. The roll is not new in principle; it is equivalent to a worker roll of the many combinations in use today and has been used by other investigators [2] in the same location as shown here. The roll is mounted at each end in a bracket which provides a screw adjustment for up-and-down and in-and-out motion. The brackets are so designed that the roll can be readily lifted out and replaced without the need of resetting. The roll is covered with metallic wire having 8 points and 22 rows per inch. The teeth are opposed to those on the cylinder. The lickerin serves as a stripper roll. The normal setting of the roll is 0.007 in. to the cylinder and 0.01 in. to the lickerin. The roll will function in either direction of rotation. When the adjacent surfaces of the roll and cylinder move in the same direction, the roll will not load. When the surfaces move in opposite directions, the roll will accumulate fibers between the teeth of the wire. However, results with the latter rotation have indicated a slightly lower nep count for an 8-hr. period. It is recommended at this time that the roll be operated with its surface turning in the same direction as the cylinder to avoid the loading condition. The recommended speed for the roll is 35 r.p.m. Investigations at 35, 50, and 75 r.p.m. showed only slight differences in favor of the low speed.

A carding action to open the tufts and distribute the fibers is provided by the teeth of the roll opposing those of the cylinder. The strips accumulated by the roll are delivered back through the feed by the lickerin, which provides some additional cleaning.

The low-pressure lickerin cover (Figure 8) is recommended as part of the SRRL card conversion to reduce fiber loss and improve cleaning below the lickerin. The granular card apparatus, by sealing the top section of the main cylinder, causes an increase in air pressure at the lickerin, which has an undesirable effect on the function of the mote knives. The low-pressure lickerin cover reduces this pressure by allowing air to escape through the incoming lap.

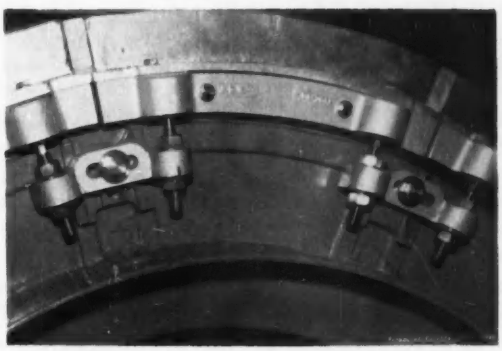

Fig. 6. Mounting brackets.

Fig. 5. Installation of PSA 3-M-Ite material.

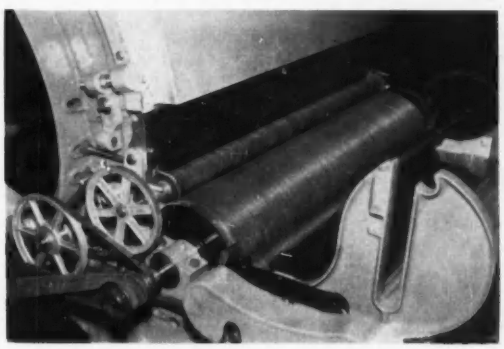

Fig. 7. Preopener roll.

Fig. 8. Low-pressure lickerin cover.

As seen in the photograph, the cover extends over the feed roll, making it unnecessary to use the scavenger roll. The section of the cover extending over the feed roll hinges up for starting a new lap. When in the up position, the cover seals off the escape of air to prevent dust and lint from blowing into the room. Laboratory evaluations have indicated that the cover is very effective with the perforated type of lickerin screen, but mill tests with the grid type of screen have not substantiated these findings. Investigations are underway to determine the effect of the different types of screens on the performance of the low-pressure cover. Work by other investigators [1] has also shown that the angle and location of the mote knives affect the trash and lint loss in the motes. With the low-pressure cover and perforated screen, it has been found that the best location for the mote knives is 1 in. clearance from the feed plate with a 14° angle. Using a 30° angle doubles the lint loss, and using a standard cover with the 30° angle doubles the lint loss again with no additional cleaning. Retaining the 14° angle and decreasing the clearance to ½ in. results in a 7% saving in fiber with a 7% decrease in cleaning.

The advantages of the SRRL card conversion are summarized below.

1. A savings in waste of 2–4% is obtained, and handling of waste is reduced by eliminating the flat strips.

2. A reduction in repair costs and parts inventories should result by changing from a complex moving mechanism to a simple stationary one.

3. A reduction in weight of about 800 lb. is realized.

4. A reduction in power requirements of 100 watts results with removal of the flats [3].

5. The sealed top of the card is a major step in the elimination of dust in the card room.

6. The smooth finish of the card has a neat appearance and simplifies good housekeeping.

7. The design of wider cards is made practical where the need exists.

Although the method of carding without flats appears attractive, there still remains much to be learned. For instance, recommendations can be made for the granule size of the granular carding surface which will give best results in a relatively new condition; however, the granule size for best average performance throughout its life can be determined only through continuous operation over a long period. Also, adjustments in the subsequent processes of drawing, spinning, winding, etc., for best results may be required, and this will take considerable time to determine.

The Granular Card is covered by U. S. Patent 2,879,549 and other applications pending. Licenses to use this patent by qualified machinery manufacturers are available on a nonexclusive, royalty-free basis. Licensed manufacturers may obtain engineering specifications and technical information from the Southern Utilization Research and Development Division, New Orleans, Louisiana, without charge.

Conclusion

A package conversion for the cotton card is now available which eliminates flat waste and decreases processing costs. While results appear favorable from limited laboratory and mill evaluations, the Granular Card is a radically new device and much remains to be learned about this development.

Acknowledgment

The card was developed in association with R. A. Rusca; the author wishes to thank Herschel W. Little for planning tests and for statistical analysis of results and A. F. Fayette and J. J. Bergquist for photographic work.

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Preliminary Mill Evaluation of the Southern Regional Research Laboratories Flatless Card[1]

G. P. Callaway

Avondale Mills, Sylacauga, Alabama

THE objectives of these tests were to evaluate the flatless card conversion developed by the Southern Utilization Research and Development Division on cards operating under normal cotton textile mill conditions.

This report covers operation of the experimental card in two plants—a sales yarn plant and a plant carding, spinning, and weaving coarse colored yarn fabrics. The sales yarn mill cards are equipped with conventional clothing using Strict Middling $1\frac{1}{16}$-in. cotton. The weaving unit uses a considerably lower grade cotton stock and cards clothed with metallic wire. There is considerable difference in draft organization, equipment, and speeds, which we believe may be considered competitive organizations for each type stock and product.

The two plants will be identified in this report as Central Plant (sales yarn mills) and Eva Jane (coarse yarn weaving unit).

Realizing testing equipment, atmospheric conditions, production equipment, and mill construction influence results, we will give details concerning these conditions.

Physical Testing Laboratory and Equipment

This laboratory is a one-story brick building, completely enclosed, with central station conditioning maintaining temperature of $70° \pm 2°$ F. with relative humidity of $65\% \pm 2\%$.

Testing Equipment Used

Shirley Analyzer	Waste content
Pressley	Fiber strength
Micronaire	Fiber fineness
Blender (Custom Scientific)	Blends
Nep Tester (Custom Scientific)	Evaluate potential neps
Uster Tester, B Model Integrator	
Recorder	Evenness and chart
Uster Spectrograph	Cycles
Spectrograph records	Cycles
Alfred Suter Automatic Yarn Reel	Skeins
Scott Tester	Yarn skein strength
Alfred Suter Yarn Quadrant	Skein weight
Uster Automatic Single-end Tester	Strength, elongation, range in strength test automatically from 10 to 200 tests per bobbin

[1] Presented at the Cotton Research Clinic of the National Cotton Council, Asheville, North Carolina, May 14, 1959.

Central Plant Construction and Machinery

The single story building is completely enclosed —air change system.

Opening, cleaning, and picking are done in the same department.

The opening line consists of seven hopper feeders, waste feeder, two No. 5 openers, two No. 4 openers, and two Super Jet cleaners in two lines feeding four one-process, two-beater pickers, rear beater Aldrich, Cylinder 150 pins, and a front beater Kirschner.

Cards

The equipment consists of a Saco Lowell 40-in. equipped with conventional clothing, No. 100 wire on cylinder, No. 110 wire on doffer.

Drawing

Drawing utilizes a two-process five-roll system; all bottom rolls are metallic.

Type of top roll covering	First process	Second process
First	Metallic	Synthetic
Second	Metallic	Synthetic
Third	Synthetic	Synthetic
Fourth	Synthetic	Synthetic
Fifth	Synthetic	Synthetic

Fly Frames

Fly frames are $10 \times 4\frac{1}{2}$ inter draft.

Spinning

Spinning details are: $3\frac{1}{2}$-in. gauge, 2-in. ring, high draft double apron system, $10\frac{1}{4}$-in. bobbin, $9\frac{1}{2}$-in. stroke, open creels, suction cleaning, and traveling frame cleaners.

Draft and Speed Organization

Picker lap is 14.35 oz.; production per picker is 338 lb./hr.

Cards

Production information follows: 50-gr. sliver, 167 r.p.m. cylinder, 790 lickerin speeds, flats 3 in./min., production per card hour (100%) 10.9 lb., grinding cycle 240 hr., stripping cycle 3 hr.

Drawing

	First process	Second process
No. ends fed	6	6
Sliver weight fed, gr./yd.	50	58
Sliver weight delivered gr./yd.	58	58
Front roll speed, ft./min.	140	145
Weight in can Breaker	14.1 lb.	
Finisher	15.8 lb.	

Roving

A 2.00 Hk. roving, 1.44 TM, was produced at 1100 spindle speed.

Spinning

A 30/1 yarn, 3.68 TM, 2.00 Hk double roving, was spun at 155 r.p.m. front roll.

Cotton Stock

An average of twenty tests were selected at random from 10 bales blended for the control test. Average commercial classification was Strict Middling $1\frac{1}{16}$ in., 50% Eastern, 50% Memphis Territory growth. Specifications were: fiber fineness, average 4.16, fine 3.6, coarse 4.9; Pressley average, 79.3; Nep Tester (Custom Scientific), 17.7; Shirley Test lint delivered, 97.4%; foreign visible matter, 0.92%, 1.68% invisible loss, total visible and invisible loss 2.6%.

Card Settings, in.

	SRRL	Conventional
1. Lap guide	39.0	39.0
2. Lower edge back plate	.015	.068
3. Upper edge back plate	.015	.022
Five points for setting flats:		
4. Backs	.012	.007
5. Int.	.010	.007
6. Int.	.007	.009
7. Int.	.007	.010
8. Front	.007	.012
9. Upper end of front knife plate	.022	.034
9A. Flat stripping comb	.015	.022
10. Lower edge front knife plate	.022	.034
11. Doffer to cylinder	.007	.007
12. Comb to doffer	.017	.022
Cylinder screen to cylinder:		
13. Front	3/16	.187
14. Middle	.068	.068
15. Back	.029	.029
16. Feed plate to lickerin	.010	.012
17. Lickerin to cylinder	.007	.007
Lickerin screen to lickerin:		
18. Front	.010	.010
Mote knives from lickerin:		
19. Bottom	.015	.007
20. Top	.015	.007
21. Angle of mote knife to lickerin, °		30
22. Hackle comb		.022

Waste Test Results

	SRRL card, %	Conventional card, %
Flat strips	—	2.822
Cylinder strips	.810	.729
Doffer strips	.161	.138
Motes and fly	1.721	1.253
Total	2.692	4.942

Card Data

	Neps/100 sq. in.	Sliver wt., gr./yd.	Uster % var.
SRRL	9.2 Av. 120 Count	50.2 Av.	2.8 Av.
Conv.	10.3 Av. 120 Count	50.5 Av.	2.9 Av.

Finisher Drawing and Roving Data

	Drawing sliver Uster % var.	Hk count	Roving Uster % var.
SRRL	4.0 Av.	1.98 Av.	7.5 Av.
Conv.	3.8 Av.	2.03 Av.	7.5 Av.

Yarn Data—30/1 Carded Yarn

	Skein strength, lb.	Single strand strength, lb.	Avg. yarn count	Strength constant
Std. card	68	.51	30.3	2060
SRRL card	67	.48	31.6	2117

(Cont.)

	Elongation, %	Uniformity (Uster), %	Yarn appearance grade
Std. card	6.3	15.9	B +
SRRL card	5.5	15.4	B −

Note: Nep counts were made for an average of four times each eight hours for a period of 14 days. The counts were taken across the web in three different sections.

Eva Jane Construction and Machinery

Eva Jane Plant is a four-story building of brick construction, windows enclosed, with air change system, located in Sylacauga, Alabama.

The Opening and Blending Department is located in a separate building, containing only hopper feeders, 400 ft. from the cleaning equipment, which is adjacent to the pickers. Pickers and cards are on the third floor.

The opening line consists of blending feeders with separate waste hopper. The stock is fed from blending feeders to mixing hopper, followed by two beater sections and two Super Jet Cleaners. This cleaning line feeds two pickers, each producing 340 lb./hr. Pickers are one-process, two-beater sections, with rear being Aldrich Beater and front Kirschner.

Cards are 40-in. Saco Lowell equipped with Ashworth metallic wire on cylinder and doffer, with steel base wire. Total weight, doffer and cylinder, of base wire and metallic clothing per card is 590 lb.; 110 conventional Saco Lowell top flats, 660 lb.; and one pair of bends, 48 lb. Weight of conventional cylinder and doffer clothing is 110 lb.

Drawing is equipped with three over four new drafting system, eight doublings, single process, with 14 × 42-in. sliver cans.

Fly frames are latest type 12 × 6½ equipped with SF2 Drafting System and Pneumastop.

Spinning is 2½-in. ring, 10-in. bobbin, 9-in. traverse, antifriction spindles, double apron drafting, open creels, suction cleaning, and traveling frame cleaners.

Draft and Speed Organization

Picker laps are 15.5 oz./yd.; total weight, 55.2 lb. Cards are 58-gr. sliver, cylinder speed 170 r.p.m., lickerin 600 r.p.m., top flat (convention card) 1¾ in./min., production 15.95 lb./hr., 100% efficiency, 15 × 42-in. sliver can.

Drawing

Drawing is eight ends up, 75-gr. drawing sliver, 130 ft./min. speed.

Slubbers

Data are: 0.68 HR, 725 r.p.m. flyer speed, 196 r.p.m. front roll, 1.27 TM.

Spinning

Spinning was 14/1 warp from 0.68 hank single roving, front roll speed 163, TM 4.22.

Cotton Stock

The following is an average of 20 tests selected at random from 10 bales blended for control tests.

Average commercial classification: Strict Low Bright Middling 1 in. (Memphis Territory); fiber fineness 3.83, fine, 3.0, coarse 4.9; Pressley average 74.4; strength index average 6.9; Nep Tester (Custom Scientific) 36 neps/100 sq. in.

Shirley test lint delivered 95.75%, visible foreign matter 1.80%, invisible loss 2.45%, total visible and invisible loss 4.25%.

Card Settings, in.

	Eva Jane Plant	
	SRRL	Conventional
1. Lap guide	39.0	39.0
2. Lower edge back plate	.068	.068
3. Upper edge back plate	.032	.022
Five points for setting flats:		
4. Backs	.007	.010
5. Int.	.007	.010
6. Int.	.007	.010
7. Int.	.007	.010
8. Front	.007	.010
9. Upper end of front knife plate	.039	.034
9A. Flat stripping comb	.022	.022
10. Lower edge front knife plate	.034	.034
11. Doffer to cylinder	.005	.005
12. Comb to doffer	.022	.022
Cylinder screen to cylinder:		
13. Front	.187	.187
14. Middle	.068	.068
15. Back	.068	.022
16. Feed plate to lickerin	.010	.010
17. Lickerin to cylinder	.007	.007
Lickerin screen to lickerin:		
18. Front	.034	.034
Mote knives from lickerin:		
19. Bottom	.010	.007
20. Top	.022	.007
21. Angle of mote knife to lickerin, °	30	30
22. Hackle comb		.022

Waste Test Results

Test No. 1

	SRRL card		Conventional card	
	lb.	%	lb.	%
Pounds fed	107.187		107.187	
Sliver delivered	104.938	97.90	103.813	96.85
Motes and fly	1.937	1.81	1.687	1.57
Sweeps	.188	.17	.250	.23
Flat strips			1.313	1.23
Invisible loss	.124	.12	.124	.12

Test No. 2

	SRRL card		Conventional card	
	lb.	%	lb.	%
Pounds fed	160.438		157.625	
Sliver delivered	157.063	97.89	152.375	96.67
Motes and fly	2.813	1.75	2.313	1.47
Sweeps	.438	.27	.438	.28
Flat strips			1.938	1.23
Invisible loss	.124	.08	.561	.36

Shirley Analysis Test Report for Card Sliver

	Weight fed, g.	Lint delivered, g.	Visible foreign matter, g.	Invisible loss, g.	Total invisible and visible loss, %
SRRL	100.0	98.4	.7	.9	1.6
Conv.	100.0	98.8	.5	.7	1.2

Card Data

	Neps/100 sq. in.	Sliver wt., gr./yd.	Uster % var.
SRRL	30.9 Av. 120 Count	57.8 Av.	2.76 Av.
Conv.	29.3 Av. 120 Count	59.5 Av.	2.14 Av.

Drawing and Roving Data

	Drawing sliver Uster % var.	Roving Uster % var.	Hk count
SRRL	2.27 Av.	6.6 Av.	.69 Av.
Conv.	2.13 Av.	6.5 Av.	.68 Av.

Yarn Data

	Break	Counts	Break constant	Uster % var.
SRRL	138 Av.	14.2 Av.	1960 Av.	16.0 Av.
Conv.	131 Av.	14.5 Av.	1900 Av.	16.0 Av.

We do not feel that ends down made from production of a single card could be considered conclusive; therefore we are not including ends down results in this report.

Three additional flatless attachments have been delivered, which we will use for further evaluation under normal mill conditions, carrying results into fabric.

The Control of Comber Noils[1]

J. F. Bogdan, Henry K. C. Woo, and C. H. Pan

Textile Research Center, School of Textiles, North Carolina State College, Raleigh, North Carolina

ONE OF the "inflexible laws of textiles" states that the removal of additional amounts of fibers during combing results in yarns of improved strength and appearance. The combed yarn spinner's conditioned reflex in the face of a customer's complaint results in his removing an additional 1% noils. This forthright plan of action demonstrates good intentions, but may have no salutary effect on yarn quality. There is an obvious extrapolation: increase to 100% the noils removed during combing and you have as nearly perfect a product being delivered by the comber as it is possible to obtain. This concept has been assailed by the unimaginative as being impractical on the grounds that it would lower comber production rates.

Combing is another textile process which inspires reverence because of its ancient age. Mechanically, the comber is one of our more complex machines. The intricate "wheels within wheels," the interdependence of the various motions during its operation, make the combing operation difficult to break down into discrete little pieces for study. What follows is an attempt to do this over a period of two years with the financial assistance of ten textile manufacturing companies.

By definition, a combed yarn is one which has been spun from stock processed through a comber; it is expected to be cleaner, smoother, and more lustrous than a carded yarn, and it is certainly more expensive. Nothing is said about the condition of the comber, its speeds, its settings, or the amount of material extracted as noils. According to this definition, legally, one can throw cotton through the slats of a picket fence, and if one has taken the precaution to hang on that fence a cast iron sign reading "Comber," one can sell the product of the cotton which reaches the other side at a high premium; this leads to the topic of "scratch combing."

Scratch combing, or fiber exercise, is the practice of processing material through a comber with the removal of an amount of noils which is well below ordinary practice. Besides the usual methods of reducing comber noils, there may be added the removal of rows of half lap needles or the adjustment of top combs so that their depth of penetration is limited. That such practices exist undetected by yarn buyers is due, in part, to the difficulty in assessing the effects of combing.

The legitimate reason for combing is to produce a product which is smoother, more uniform and lustrous, and which can be spun to finer counts with improved yarn strength. Many mills adjust noil percentages in an attempt to achieve these goals by changes in step gauge setting; the distance between the most forward position of the nipper and the bottom detaching roll. Other factors to be considered in the effort to control comber noils are listed below.

- Cotton
- Lap preparation
  - Process
  - Weight
- Comber
  - Speed
    - Nips per minute
    - Lap feed per nip
  - Timing
    - Lap feed
    - Nipper knife
    - Detaching roll
    - Top comb
  - Settings
    - Feed roll to nipper
    - Nipper to detaching roll
    - Top comb depth
    - Top comb angle
    - Top comb to bottom detaching roll
    - Top comb to top detaching roll

Figure 1 shows the improvement in yarn appearance and yarn strength which results from a good job of combing. Figure 2 shows the Suter-Webb

[1] Presented at the Cotton Research Clinic of the National Cotton Council, May 14, 1959.

weight distribution by fiber length groups of card sliver, comber sliver, and comber noils. It can be seen that combing removes a larger proportion of the short fibers, resulting in a combed sliver which has a longer fiber mean length than before combing.

The method of preparing the lap for feeding to the comber affects both the amount of noils removed, if no changes in settings are made, and the strength and appearance of the resulting yarn. In Figures 3 and 4, the code for the various comber lap preparation processes after carding is

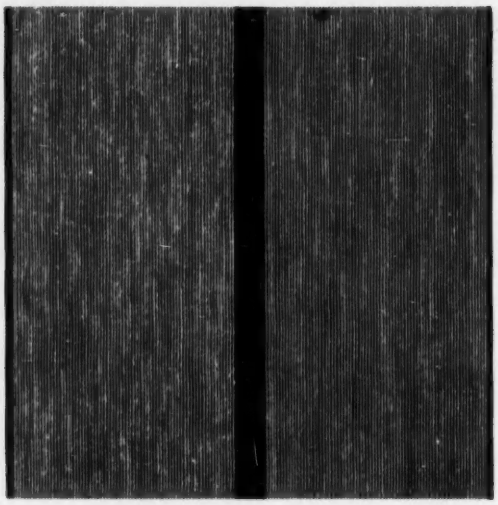

Fig. 1. SM cotton, 1 1/32 in. Left, carded (CS = 2100); right, combed (CS = 2600).

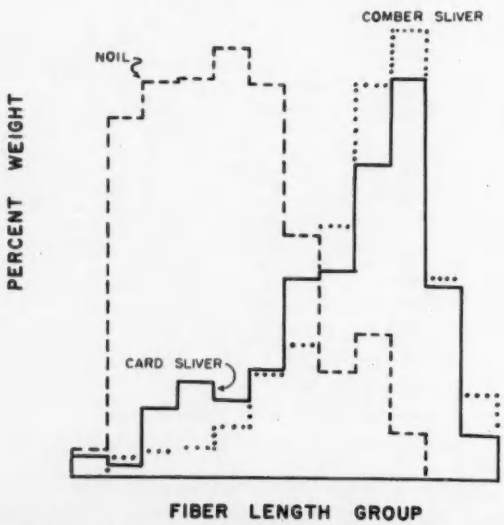

Fig. 2. Weight distribution by fiber length groups.

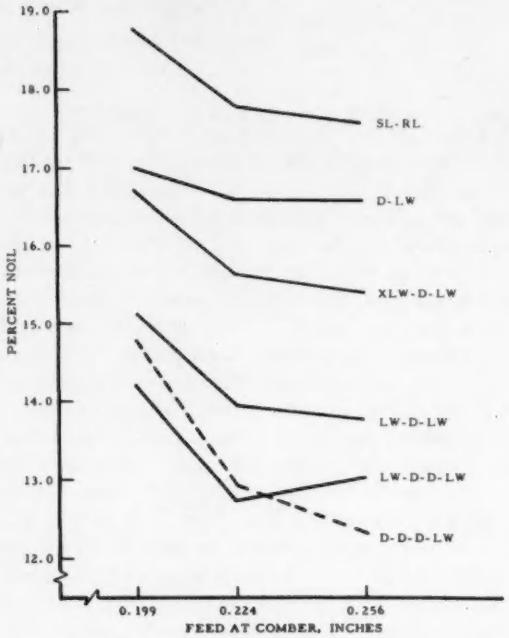

Fig. 3. Percent noil by lap preparation and feed; Saco-Lowell comber.

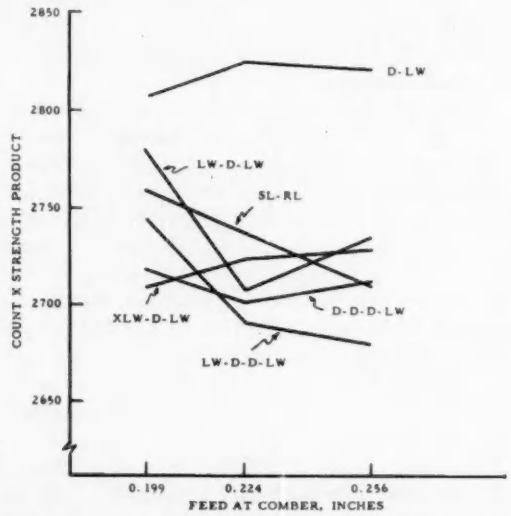

Fig. 4. Count × strength product by lap preparation and feed at comber; Saco-Lowell.

TABLE I. Lap Preparation, Lap Weight, Feed and Step Gauge Settings-Percent Comber Noil (Saco-Lowell Comber)

"F" Cotton
$1\frac{1}{32}$ in., SM

Lap preparation	Lap weight, gr./yd.	Feed at comber, in.	Step gauge setting, in.			
			8/32	9/32	10/32	12/32
D-LW	600	0.26	12.3		15.6	20.6
		0.20	11.3		17.3	19.6
	850	0.26	11.9		16.5	20.5
		0.20	12.0		17.1	18.4
LW-D-D-LW	600	0.26	9.2		12.9	17.1
		0.20	9.7		13.7	16.0
	850	0.26	8.4	10.8	12.4	16.8
		0.20	9.0	9.1	14.2	14.3

TABLE II. Lap Preparation, Lap Weight, Feed and Step Gauge Settings-Count × Strength Product (Saco-Lowell Comber)

"F" Cotton
$1\frac{1}{32}$ in., SM

Lap preparation	Lap weight, gr./yd.	Feed at comber, in.	Step gauge setting, in.			
			8/32	9/32	10/32	12/32
D-LW	600	0.26	2592		2597	2562
		0.20	2522		2691	2640
	850	0.26	2626		2540	2574
		0.20	2643		2626	2650
LW-D-D-LW	600	0.26	2598		2600	2601
		0.20	2621		2654	2666
	850	0.26	2523	2536	2649	2640
		0.20	2565	2584	2655	2646

TABLE III. Lap Preparation, Lap Weight, Feed and Step Gauge Settings-Percent Comber Noil (Whitin Comber)

"D" Cotton
$1\frac{1}{16}$ in., SM

Lap preparation	Lap weight, gr./yd.	Feed at comber, in.	Step gauge setting, in.			
			9/32	10/32	11/32	13/32
D-LW	600	0.24	18.4		28.4	29.4
		0.20	18.6		24.2	32.4
	850	0.24	18.3		22.3	27.4
		0.20	17.1		21.7	32.5
LW-D-D-LW	600	0.24	14.5		23.1	26.2
		0.20	15.2		22.5	28.6
	850	0.24	13.5	17.8	22.1	23.6
		0.20	13.6	18.0	19.4	28.3

TABLE IV. Lap Preparation, Lap Weight, Feed and Step Gauge Settings-Count × Strength Product (Whitin Comber)

"D" Cotton
1 1/16 in., SM

Lap preparation	Lap weight, gr./yd.	Feed at comber, in.	Step gauge setting, in. 9/32	10/32	11/32	13/32
D-LW	600	0.24	2602		2762	2734
		0.20	2627		2665	2751
	850	0.24	2638		2680	2774
		0.20	2614		2630	2729
LW-D-D-LW	600	0.24	2715		2835	2781
		0.20	2603		2700	2754
	850	0.24	2628	2683	2696	2706
		0.20	2529	2650	2660	2749

TABLE V. Step Gauge Setting

Lap Preparation: Draw-Lap Winder, Lap Weight (gr./yd.): 600, Feed at Comber: 0.26 in./Nip

Step gauge setting, in.	Percent noil	Skein break	Yarn no.	C×S	Twist multiplier	Uniformity Percent variation	Uniformity Integrator
8/32	12.3	88.2	29.4	2592	4.28	80	12.9
10/32	15.6	85.4	30.4	2597	4.17	74	12.7
12/32	20.6	84.8	30.2	2562	4.22	71	11.3

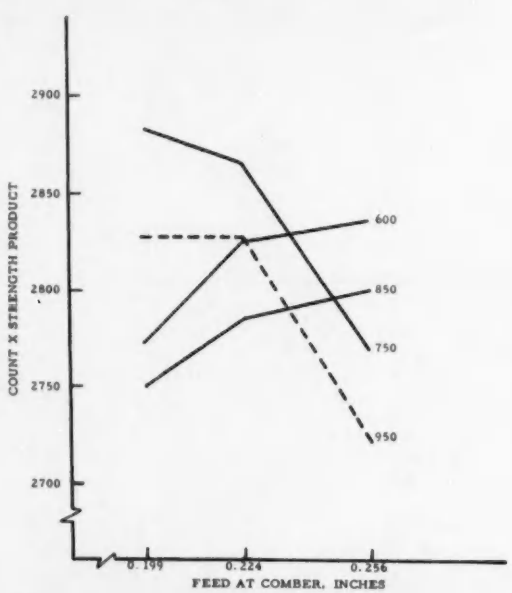

Fig. 5. Count × strength product by lap weight and feed at comber; Saco-Lowell. Lap preparation: drawing, lap winder.

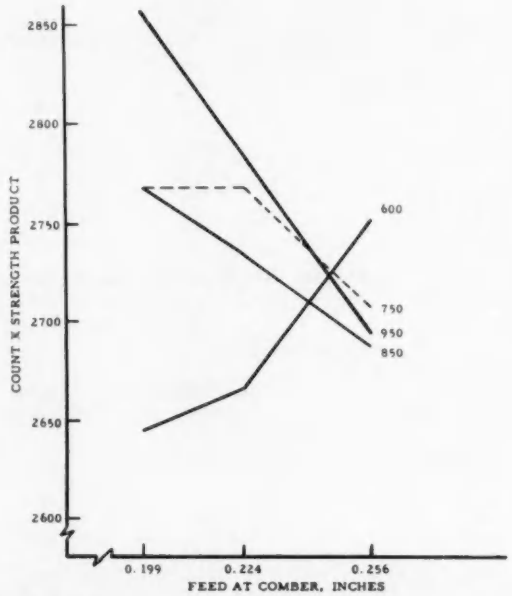

Fig. 6. Count × strength product by lap weight and feed at comber; Saco-Lowell. Lap preparation: sliver lapper, ribbon lapper.

SL—Sliver lapper
RL—Ribbon lapper
D—Drawing
LW—Lap winder
XLW—Slivers reversed before lap winding

Figures 5 and 6 illustrate the effects of lap weights and the amount of lap fed per nip for two different methods of comber lap preparation.

Tables I, II, III, and IV show the interaction of lap weight, feed, and step gauge settings for two lap weights and two combers.

Lighter comber lap weights do not necessarily result in better combing. Figure 7 attempts to demonstrate in an idealized manner how light slivers spaced without sufficient contact may result in lack of fiber control at the nipper pressure point during the combing cycle.

For a single overlap of a comber piecing it is required that the piecing be symmetrical about its midpoint and that the piecing overlap exactly half the previous piecing. Figure 8 shows symmetrical and nonsymmetrical idealized piecings. Figures 9 and 10 show the weight distribution of piecings at various increments along their lengths; these data were obtained by cutting and weighing. It can be

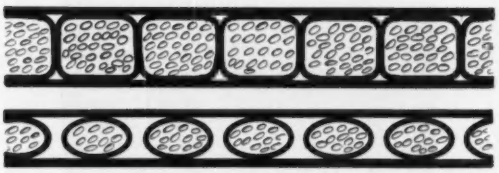

Fig. 7. Lap weight and fiber control. Top, heavy; bottom, light.

TABLE VI. Comparison of NCS Comber Settings vs. Mill Settings-Percent Noils and Count × Strength Product

Mill	Cotton	Mill settings % Noils	Mill settings CXS	NCS settings % Noils	NCS settings C×S	% Savings in noils
A	1 3/32 in. SM	15.0	2506	11.8	2588	3.2
A	1 3/32 in. SM	14.7	2710	12.3	2714	2.4
E	1 3/32 in. SLM	12.9	2709	10.6	2785	2.3
F	1 3/32 in. SM	13.7	2259	11.0	2280	2.7
H	1 1/16 in. SM	13.5	2691	11.0	2692	2.5
K	1 1/16 in. SM	14.1	2280	10.6	2300	3.5
K	1 1/16 in. SM	13.2	2498	10.5	2501	2.7
L	SLM and SM	14.8	2387	13.0	2420	1.8
				Average Savings in Noil		2.6%

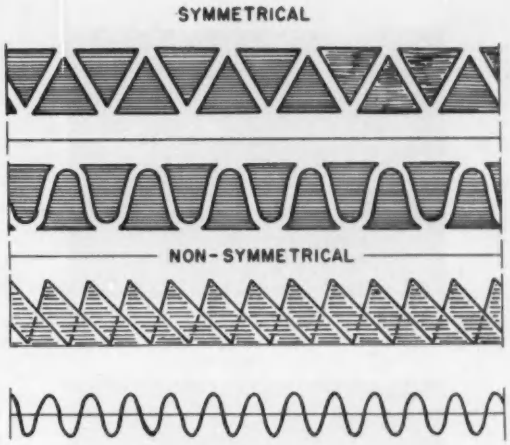

Fig. 8. Comber piecing overlap.

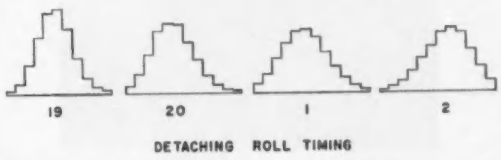

Fig. 9. Weight distribution of piecing; Saco-Lowell comber. Step gauge setting, 5/8 in.; feed, 0.224 in./nip.

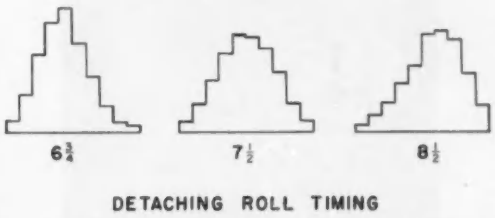

Fig. 10. Weight distribution of piecing; Whitin comber. Step gauge setting, ½ in.; feed, 0.196 in./nip.

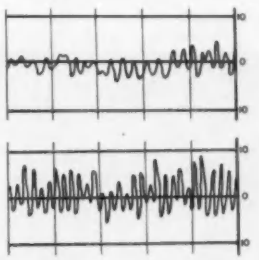

Fig. 11. Sliver variations; detaching roll timing. Nasmith comber, individual head; cotton, 1 1/16 in. M. Top: timing, 2½; average maximum variation, 17%. Bottom: timing, 3; average maximum variation, 25%.

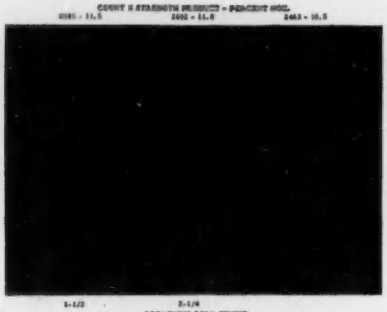

FIG. 12 DETACHING ROLL TIMING
1-1/16" - Sbl. HABNITH COMBER. STEP GAUGE SETTING - 88/32"

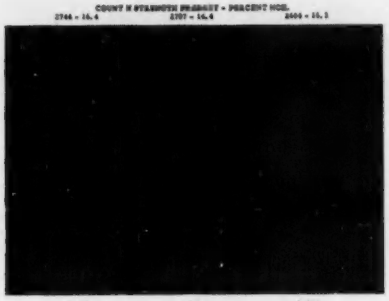

FIG. 13 DETACHING ROLL TIMING
1-1/16" - Sbl. HABNITH COMBER. STEP GAUGE SETTING - 11/32"

FIG. 14 MILL SETTINGS NCS I NCS II
1-1/16" - Sbl. SACO-LOWELL COMBER
TWO DRAWINGS

FIG. 15 MILL SETTINGS NCS I NCS II
1-1/16" - Sbl. SACO-LOWELL COMBER
AFTER COILER. WITHOUT DRAWING

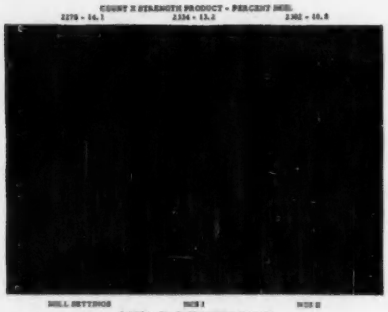

FIG. 16 MILL SETTINGS NCS I NCS II
1-1/16" - Sbl. SACO-LOWELL COMBER
INDIVIDUAL COMBER HEAD SLIVER. WITHOUT DRAWING

FIG. 17 MILL SETTINGS NCS I NCS II
1-1/32" - SLM. WHITIN COMBER
ONE DRAWING

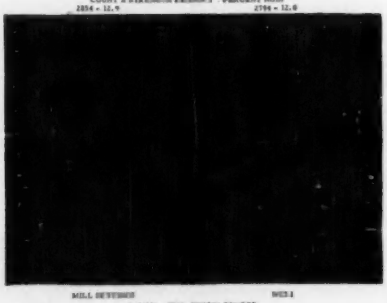

FIG. 18 MILL SETTINGS NCS I
1-1/32" - SLM. WHITIN COMBER
AFTER COILER. WITHOUT DRAWING

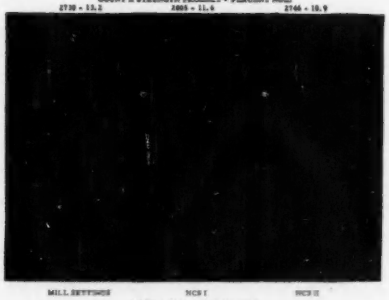

FIG. 19 MILL SETTINGS NCS I NCS II
1-1/32" - SLM. WHITIN COMBER
INDIVIDUAL COMBER HEAD SLIVER. WITHOUT DRAWING

seen how the balance of weight shifts with changes in detaching roll timing.

Figure 11 shows the effect on the uniformity of the sliver produced by the comber with different detaching roll timings. The charts are copies of actual Saco-Lowell Sliver Tester charts.

Figures 12 and 13 illustrate the yarns obtained by changes in detaching roll timing.

Table VI shows a comparison between the noils and break factors obtained by using the mill settings and the settings given in the Comber Organization tables. It will be noted that it is possible to reduce noils without affecting adversely yarn strength.

Table VII and Figures 14, 15, and 16 show the testing details for yarns spun from normally processed material, from comber sliver which had not

TABLE VII. N. C. State Settings and Mill Settings

Cotton—"K," 1 1/16 in. SM
Comber—Saco-Lowell

Comber organization	Top comb to: Bottom detaching roll, in.	Top comb to: Top detaching roll, in.	Edfors motion index	Comber: Percent noil	Comber: Sliver weight, gr./yd.	Comber: Sliver variation, %	Drawing: Sliver weight, gr./yd.	Drawing: Sliver variation, %	Skein break	Yarn no.	C×S	Twist multiplier	Uniformity: Percent variation	Uniformity: Integrator
Yarn spun from comber sliver run through two drawing processes														
Mill settings	.050	.050	17¼	14.1	60	15.4	59	8.7	76.5	29.8	2280	3.39	84	12.1
NCS settings I	.070	.030	16½	13.4	60	14.5	61	7.4	76.6	30.2	2313	3.39	86	12.0
NCS settings II	.090	.030	16	10.6	62	14.9	62	7.2	78.8	29.2	2300	3.51	85	11.5
Mill production	—	—	—	14.0	—	—	—	—	72.2	30.7	2218	3.39	89	11.9
Yarn spun from comber sliver after coiler without drawing														
Mill settings	.050	.050	17¼	14.1	60	15.4			72.5	31.5	2283	3.33	84	12.1
NCS settings I	.070	.030	16½	13.4	60	14.5			77.6	30.8	2390	3.33	82	11.8
NCS settings II	.090	.030	16	10.6	62	14.9			75.8	30.5	2311	3.37	87	12.2
Yarn spun from individual comber head sliver without drawing														
Mill settings	.050	.050	17¼	14.1	98	12.4			72.8	31.3	2278	3.34	81	13.3
NCS settings I	.070	.030	16½	13.2	96	13.9			79.4	29.4	2334	3.42	77	12.6
NCS settings II	.090	.030	16	10.8	100	12.5			78.3	29.4	2302	3.43	83	12.6

TABLE VIII. N. C. State Settings and Mill Settings

Cotton "E," 1 3/32 in. SLM
Comber—Whitin J

Comber organization	Comber: Percent noil	Comber: Sliver weight, gr./yd.	Comber: Sliver variation, %	Drawing: Sliver weight, gr./yd.	Drawing: Sliver variation, %	Skein break	Yarn no.	C×S	Twist multiplier	Uniformity: Percent variation	Uniformity: Integrator
Yarn spun from comber sliver run through one drawing process											
Mill settings	12.9	56	19.4	57	10.8	122	22.2	2709	3.74	64	10.1
NCS settings I	12.0	60	19.3	59	11.6	131	21.6	2827	3.76	65	11.0
NCS settings II	10.6	59	21.0	59	11.6	127	22.0	2785	3.72	66	10.9
Mill "E" production	13.0	—	—	—	—	102	23.7	2446	3.58	93	12.5
Yarn spun from comber sliver after coiler without drawing											
Mill settings	12.9	56	19.4	—	—	128	22.3	2854	3.66	65	10.6
NCS settings I	12.0	60	19.3	—	—	124	22.5	2794	3.54	66	10.9
Yarn spun from individual comber head sliver without drawing											
Mill settings	13.2	89	13.9	—	—	120	22.8	2730	3.53	63	11.8
NCS settings I	11.6	91	13.2	—	—	131	21.4	2805	3.76	66	13.4
NCS settings II	10.9	91	15.0	—	—	121	22.7	2746	3.55	64	11.0

TABLE IX. Top Detaching Roll to Top Comb Setting

Cotton—"H"
Step Gauge Setting—$\frac{1}{32}$ in.
Top Comb to Bottom Detaching Roll—$\frac{1}{16}$ in.
Top Comb Angle—1°
Comber—Nasmith
Feed at Comber—5T
Tension Draft—1.10
Top Comb Depth—$\frac{1}{16}$ in.
Feed Roll Setting—$\frac{1}{16}$ in.

Top detaching roll to top comb, in.	Detaching roll timing	Sliver weight, gr./yd.	Percent sliver variation	Percent noil	Skein break	Yarn no.	C×S	Twist multiplier	Uniformity: Percent variation	Uniformity: Integrator
.110	$1\frac{1}{2}$	61	38.4	12.5	61.7	37.2	2295	4.51	97	23.8
.006	$2\frac{1}{4}$	63	16.4	11.0	74.0	36.4	2692	4.67	91	14.5

TABLE X. Nasmith Comber Organization

	$1\frac{1}{16}$ in. SM	
	N.C.S.	Mill setting
Percent noil	11	13.5
Weight of lap, gr./yd.	650	650
Weight delivered, gr./yd.	60	60
Length fed per nip	0.25	0.25
Timing (index wheel)		
Feeding	2–19	2–19
Detaching	$2-\frac{1}{4}$	$1-\frac{1}{2}$
Settings		
Feed ratchet pick	5T	5T
Feed roll front to nipper knife back (nipper closed), in.	$\frac{13}{16}$	$\frac{13}{16}$
Cushion plate to needle points, in.	.035	—
Cushion plate to detaching roll (step gauge setting), in.	$\frac{10}{32}$	$\frac{10}{32}$
Top comb angle, °	1	8
Top comb to the back of the top detaching roll, in.	.006	.020
Depth of top comb, in.	$\frac{1}{16}$	$\frac{1}{16}$
Top comb to back of the bottom detaching roll, in.	$\frac{1}{16}$	$\frac{1}{16}$

been drawn, and from sliver taken from an individual head without processing through the comber draw box. Table VIII and Figures 17, 18, and 19 give similar information for another type of comber.

Half laps contain some seventeen rows of needles which are used to comb the front half of the piecing. The back half is combed by a single row of needles, the top comb. It can be seen, then, that the setting of the top comb must be critical and important. Figure 20 shows the evenness charts obtained for two top comb to top detaching roll settings. The effect on the sliver uniformity is evident. Table IX shows the yarn testing details and Figure 21 shows the change in yarn appearance.

The setting of the top comb to the bottom detaching roll influences noils and yarn strength. Figure

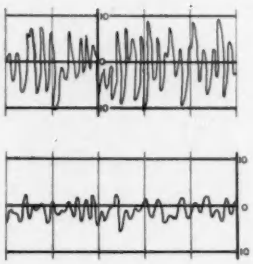

Fig. 20. Sliver variation; top comb to top detaching roll setting. Nasmith comber, individual head; cotton, $1\frac{1}{16}$ in. M. Top: top comb setting, 0.110 in.; average maximum variation (yd./yd.), 38%. Bottom: top comb setting, 0.006 in.; average maximum variation (yd./yd.), 17%.

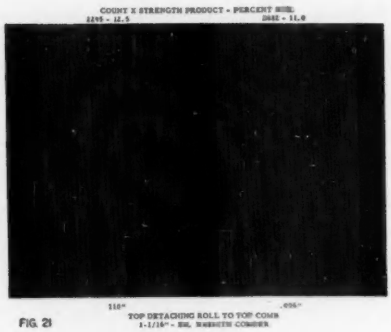

FIG. 21

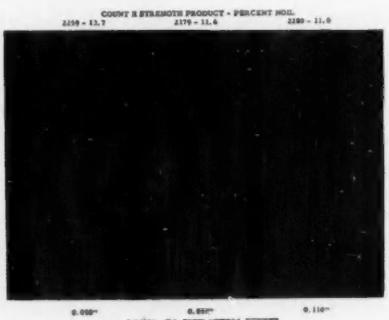

FIG. 22

TABLE XI. Saco-Lowell Comber Organization

	1 1/32 in.		1 1/16 in.		1 3/32 in.	
	NCS I	NCS II	NCS I	NCS II	NCS I	NCS II
Percent noil	11½	11	13	10½	14	11½
Weight of lap, gr./yd.	800–840	800–840	800	800	800–840	800–840
Weight delivered, gr./yd.	59	60	59	62	60	60
Length fed per nip, in.	0.221	0.221	0.236	0.236	0.236	0.236
Timing						
Detaching index	¾	¾	1	1	1¼	1¼
Edfors motion index	16	16	16½	16	16	16
Settings						
Feed ratchet	16T	16T	15T	15T	15T	15T
Feed roll front to nipper knife back (nipper closed), in.	0.100	0.100	0.100	0.100	0.100	0.100
Cushion plate to needle points, in.	0.025	0.025	0.025	0.025	0.025	0.025
Cushion plate to detaching roll (step gauge setting), in.	0.280	0.280	0.290	0.290	0.320	0.320
Top comb angle, °	8	8	8	8	4	4
Top comb to back of top detaching roll, in.	0.100	0.140	0.030	0.030	0.070	0.080
Depth of top comb, in.	0.025	0.025	0.010	0.010	1/16	1/16
Top comb to back of bottom detaching roll, in.	0.090	0.110	0.070	0.090	0.090	0.110

TABLE XII. Whitin Comber Organization

	1 1/16, 1 1/32 in.—SM, M		1 1/16 in.—SLM, SM		1 3/32 in.—SLM	
	NCS I	NCS II	NCS I	NCS II	NCS I	NCS II
Percent noil	12	10½	14	13	12	10½
Weight of lap, gr./yd.	725–800	725–800	725	725	725–800	725–800
Weight delivered, gr./yd.	60	60	54	54	60	60
Length fed per nip, in.	0.209	0.209	0.209	0.209	0.209	0.209
Roll diameter, in.						
Feed roll	1	1	1	1	1	1
Bottom detaching roll	1⅛	1⅛	1⅛	1⅛	1⅛	1⅛
Top detaching roll	15/16	15/16	15/16	15/16	15/16	15/16
Timing (index wheel)						
Detaching roll forward	7½	7½	7½	7½	7½	7½
Feed roll ratchet click	8¾	8¼	8¾	8¼	8¾	8¼
Settings						
Feed roll ratchet	15T	15T	15T	15T	15T	15T
Feed roll front to nipper knife back (nipper closed), in.	⅛	3/16	⅛	3/16	⅛	⅛
Cushion plate to needle points, in.	0.034	0.034	0.034	0.034	0.034	0.034
Cushion plate to detaching roll (step gauge setting), in.	¼	¼	¼	¼	¼	¼
Top comb to the back of the top detaching roll, in.	0.034	0.034	0.034	0.034	0.034	0.034
Depth of top comb	Standard Gauge	Standard plus 1/16 in.	Standard Gauge	Standard plus 1/16 in.	Standard Gauge	Standard plus 0.025 in.

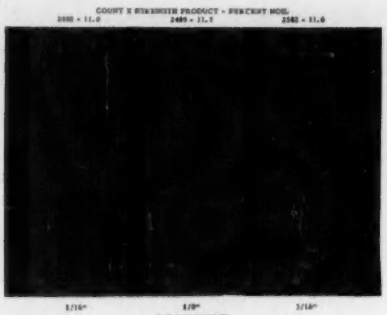

FIG. 23

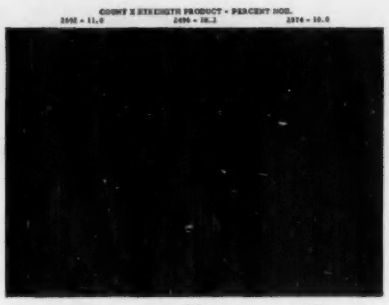

FIG. 24

22 shows yarns produced with three variations of this setting.

Figures 23 shows the effect on comber noils and yarn strength of deeper penetration of the top comb.

The setting of the nipper to the nipper knife influences yarn strength and comber noils. Figure 24 shows these details and the difference in yarn appearance.

Supporting Mills

The research on which this report is based was conducted over a two-year period at the Textile Research Center, School of Textiles, N. C. State College, under an arrangement whereby the results were the property exclusively of supporting mills for a period of one year after completion of the study. This period has expired, and the results of the project are being made public in this report.

The mills that cooperatively supported this project were The American Thread Company, Avondale Mills, Burlington Industries, Inc., Reeves Brothers, Inc., A. M. Smyre Manufacturing Company, Swift Spinning Mills, Inc., Textiles—Incorporated, United Merchants and Manufacturers, Inc., U. S. Rubber Company, and Washington Mills Company.

Correction

The figures in Table I of the paper by Gintis and Mead (TEXTILE RESEARCH JOURNAL **29**, 580, July 1959) given under "Tenacity, g./tex," should be corrected. Linear density in tex = den./9; therefore, tenacity in g./tex = g./den. × 9, not g./den. ÷ 9.

Effects of Gin Drying and Cleaning Practices on Properties of Bleached and Resin Treated Fabrics[1]

James N. Grant, Frederick R. Andrews, and Ruby H. Tsoi

Southern Regional Research Laboratory,[2] New Orleans, Louisiana

Abstract

Fabrics made from lint cotton subjected to twelve combinations of ginning practices —seed cotton cleaning, lint cleaning, and drying levels—were tested as gray, bleached, and resin treated fabrics. The seed cottons dried to the lowest moisture level before ginning produced the weakest gray fabrics. Bleaching caused no accentuation of their differences in breaking and tearing strengths which could be associated with the ginning practice since strengths of all twelve fabrics were reduced about the same amounts. Resin treatment and laundering decreased the differences in strengths among fabrics. Density of cellulose was slightly higher for the three lots dried to the lowest moisture level. Moisture regains of the bleached fabrics were essentially equal. Alkali centrifuge swelling values were more closely associated with fiber fineness than with the ginning practices. Among the fabrics, differential dyeing detected differences associated with fiber fineness but not with ginning practices. Degree of polymerization was reduced by bleaching but showed no consistent relation to seed cotton treatment. Inconsistencies among samples within groups do not permit conclusions to be reached as to effects of seed cotton cleaning or lint cleaning.

Introduction

The practice of drying seed cotton to reduce moisture in the lint prior to cleaning or ginning is common in gins throughout the country. Results reported from several investigations [2, 3, 4, 5, 6, 7, 9, 10, 11] have shown that certain fiber properties are adversely affected when moisture in the lint prior to ginning is reduced to an extremely low level. Complaints are prevalent in the industry about the processing characteristics of the cottons and reduction in qualities of textile fabrics caused by excessive drying [2, 9]. In several investigations the combined effects of drying, ginning, and seed cotton and lint cleaning on properties of the fibers have been measured [4, 5, 6, 9]. However, the contribution of each element of the combination of ginning practices to the changes in fiber properties has not been fully established.

In the present investigation efforts were made to separate the relative contributions of three ginning practices—seed cotton cleaning, moisture level in drying, and extent of lint cleaning—as causes of fiber damage which may contribute to the difficulties in processing and the reduction in fabric qualities. The ginning practices, fiber properties, processing performance at the mill, and qualities of the fabrics produced from the cotton have been described elsewhere [10, 11, 12]. In this report are presented several properties of gray, bleached, resin treated, and laundered fabrics from the twelve combinations of the ginning practices mentioned above. The fabric properties in relation to fiber and cellulose properties and their changes with drying are discussed.

Experimental

Samples

The fabrics with 30/1 warp and 40/1 filling were of 68 × 72 print cloth construction as produced in a commercial mill. The twelve fabrics were made from lint subjected to combinations of gin cleaning and drying treatments consisting of two levels of drying, moderate or elaborate seed cotton cleaning, and three levels of lint cleaning. Detailed description of the fabrics, ginning practices, and processing characteristics of the lint were given in earlier reports [10, 11, 12].

[1] Presented at the Cotton Research Clinic, May 12-14, 1959.

[2] One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture.

Treatments

The chemical processes used for desizing, scouring, bleaching, and resin treatment of the fabrics were pilot plant and research procedures. However, they follow adopted industrial practices found satisfactory for control of process variables. The chemical processes through bleaching were carried out on a continuous fabric consisting of a 5-yd. length of each of the fabrics produced from lint of the twelve combinations of ginning practices. These lengths when sewed together with leader and tail sections produced about 70 yd. of fabric.

The desizing, scouring, and bleaching processes were applied in a winch. The desizing solution consisted of 0.25% Rhozyme BX [3] and 0.10% Igepon T51, as a wetting agent, in water at 160° F. The fabrics were agitated in the desizing solution for 2 hr., then scoured for 2 hr. in a solution of 2% caustic and 0.1% Igepon T51 in water at 200° F. The peroxide bleach was 1% hydrogen peroxide and 2% sodium silicate in water at 200° F. The percentages in each solution are by volume. After being bleached for 1.5 hr., the fabrics were washed and stretched to approximately their original width while drying on the tenter frame.

Swatches (11 × 12 in.) were cut from the central areas of the 5-yd. lengths for resin treatment and for physical tests. Three swatches from each bleached fabric were resin treated by dipping in a solution prepared from 140 g. dimethylol urea (Rhonite 1) and 15 g. of 35% zinc nitrate (Catalyst H-7) in 845 g. of water. The wet fabrics were passed through squeeze rolls to restrict the wet pickup to about 80–85% of the dry weight. The dipping and squeeze roll procedures were repeated on each section before stretching to their prewet dimensions and clamping on a curing frame. The resin treated fabrics were dried for 7 min. at 140° F. and cured for 3 min. at 320° F. All resin treated samples were washed with Triton X100 detergent through one complete cycle in a home type automatic washing machine set for "Modern Fabrics" and dried in a tumble drier.

Test Methods

The methods used to evaluate the strip breaking strength [1a], tongue tearing strength [1a], flexing and abrasion resistance [1b], crease recovery [1c], air permeability [1d], degree of polymerization [1e], moisture regain [1f], differential dye behavior [1g], Elmendorf tearing strength [1h], weight, thickness, and yarn count [1a] of fabrics were those of ASTM. Other tests for measuring the differences among fabrics have included cellulose density [8], alkali swelling [5, 7], stiffness [13], and microscopical examination of fiber cell wall [7]. Fiber and fabric properties affected by moisture were measured under controlled atmospheric conditions, 70° F., 65% RH.

[3] The mention of trade names does not imply their endorsement by the Department of Agriculture over similar products not mentioned.

Results

Test results indicated that differences among fabrics for several properties (crease recovery, stiffness, air permeability, weight, thickness, and yarn count) were either too small or too inconsistent to be useful in estimating any changes which could be associated with ginning practices. Small differences among several fabrics were observed in other properties which will be discussed below.

In Table I are given moisture regains for lint at the gin, for card sliver, and for bleached and resin treated fabrics at standard conditions. Reports by others have shown that the spreads in moisture regains for cottons having different moisture levels decrease as the lint passed through stages of mechanical processing [11]. After card sliver and bleached or resin treated fabrics were permitted to condition in a standard atmosphere, the moisture differences within a series were too small to be significant. The moisture regains decreased from card sliver to bleached fabrics to resin treated.

Also given in Table I are the resin add-on, expressed as percentage increases in dry weights. The spread among the twelve fabrics of 0.5% (4.8–5.3%) is within the range found frequently from replicate treatments on one fabric. No trends in resin add-on or nitrogen contents (not given) related to ginning practices could be detected.

The fiber and yarn properties of cottons from the twelve combinations had shown differences associated with the ginning practices [11]. Therefore, fabric properties usually affected by differences in yarn properties were measured on these fabrics. While the gray fabrics are seldom used as print cloth without removing the sizing and native noncellulosic constituents, their properties are useful in assigning a market value [12]. In evaluating the effects of ginning practices, gray fabrics were included to deter-

mine changes during the bleaching and resin treatments.

Since yarn size and twist differ in the warp and filling, properties were measured in both directions. The results are reported as the sum of values for warp and filling, but the relative percentages for each are given. When conclusion differs appreciably in the analysis of data on warp and filling separately, measurements taken in both directions are discussed.

In Figure 1 are given the breaking strengths for 1-in. strips (corrected to equal number of yarns) from the gray, bleached, and resin treated fabrics for each of the combinations of ginning practices. In the gray fabrics, the average breaking strength for the filling was 81% of that for the warp, while in the bleached it was 78%. The breaking strength for the bleached fabric was consistently less than that of the gray, averaging 9% for the twelve fabrics.

In both the gray and the bleached series, the fabric with the lowest strength was produced from a combination of ginning practices consisting of the lowest moisture regain at the gin (1.7%), elaborate seed cotton cleaning, and one lint cleaner. Two other gray fabrics from this group (no lint cleaner and two lint cleaners, regains of 2.6 and 2.8%, respectively) also had low strengths. These three lots with low moisture regains and high percentages of short fibers in the lint [11] produced fabrics with the lowest strengths. Groups having equivalent moisture levels (5.0 and 5.6% moisture regains, from elaborate and moderate seed cotton cleanings, respectively) showed no consistent differences in fabrics associated with

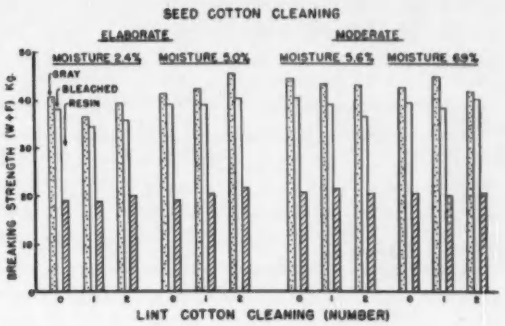

Fig. 1. The breaking strengths of warp and filling for the gray, bleached, and resin treated fabrics produced from lint of the twelve combinations of ginning practices.

TABLE I. The Moisture Regains for Lint and Fabrics and the Resin Add-on to Fabrics Made from Gin Lint from Combinations of Ginning Practices

	Moisture regain, %				
	Lint		Fabrics		
Gin treatment	Gin*	Card sliver†	Bleached†	Resin treated†	Resin add-on, %
Elaborate seed cotton cleaning					
Low moisture:					
No lint cleaner	2.7	7.5	6.6	5.7	5.0
1 lint cleaner	1.7	7.6	6.6	5.7	4.9
2 lint cleaners	2.9	7.5	6.7	5.7	5.1
High moisture:					
No lint cleaner	4.4	7.7	6.7	5.6	5.3
1 lint cleaner	5.1	7.8	6.8	5.8	4.8
2 lint cleaners	5.6	7.6	6.6	5.7	5.0
Moderate seed cotton cleaning					
High moisture:					
No lint cleaner	6.8	7.6	6.6	5.7	4.9
1 lint cleaner	5.5	7.6	6.6	5.7	4.9
2 lint cleaners	4.6	7.3	6.6	5.8	4.8
Very high moisture:					
No lint cleaner	7.4	7.6	6.7	5.7	5.2
1 lint cleaner	6.8	7.7	6.7	5.7	5.0
2 lint cleaners	6.4	7.6	6.6	5.6	5.3

* Moisture regain calculated from moisture contents reported by Agricultural Marketing Service [11].
† Moisture regain at 70° F., 65% RH.

either seed cotton or lint cleaning. The group with the highest regain at the gin (6.9%) also had about the same properties as the 5.0 and 5.6% groups.

The elongations of fabrics were rather uniform in the fillings with ranges of 15–17% for the gray and 20–22% for the bleached. However, the spread of elongations for warp directions was greater, ranging in the gray fabrics from 9 to 14% and in the bleached from 15 to 18%. The two gray fabrics with the highest and lowest elongations in the warp direction had the highest and lowest breaking strength, respectively.

An earlier report has shown that differences in strengths of yarns from which the fabrics were woven were correlated with the percentages of fibers shorter than $\frac{1}{2}$ in. in the lint and with the bundle strengths at $\frac{1}{8}$-in. gauge [12]. Both of these lint properties are related to gin practices. Properties of the cellulose, measured on the bleached fabrics or the lint (Table II), have indicated other small differences among cottons from certain combinations of practices. The cellulose for the three lots dried to the lowest moisture regains had the highest densities, but this small increase in density caused no detectable differences in

TABLE II. Properties of the Fibers and the Cellulose of Cottons Subjected to Combinations of Ginning Practices. (Gin Lint and Bleached Fabrics)

Gin treatment	Density of cellulose (fabric), g./cc.	Differential dye (fabric) rank*	Degree of polymerization (fabrics)	Degree of polymerization (lint)	Alkali swelling (lint), %	Fineness (lint), micronaire unit
Elaborate seed cotton cleaning						
Low moisture:						
No lint cleaner	1.5453	3	2860	—	200	4.5
1 lint cleaner	1.5454	4	2700	—	196	4.7
2 lint cleaners	1.5447	4	2910	4710	204	4.4
High moisture:						
No lint cleaner	1.5428	3	—	—	200	4.5
1 lint cleaner	1.5418	3	—	—	198	4.5
2 lint cleaners	1.5428	1	2880	4590	192	4.7
Moderate seed cotton cleaning						
High moisture:						
No lint cleaner	1.5416	2	2890	4390	194	4.7
1 lint cleaner	1.5426	1	—	—	189	4.8
2 lint cleaners	1.5431	2	—	—	191	4.8
Very high moisture:						
No lint cleaner	1.5433	3	2910	4610	195	4.5
1 lint cleaner	1.5413	2	—	—	193	4.6
2 lint cleaners	1.5425	2	—	—	190	4.8

* Rank-shades: (1) red, (4) greenish.

TABLE III. The Effects of Laundering on Shrinkage and Breaking and Tearing Strengths of Gray and Bleached Fabrics Made From Lint of Gin Dried Cottons

Gin moisture	Fabric shrinkage, %		Decrease in breaking strength, %		Tearing strength, kg.	
	Gray	Bleached*	Gray	Bleached	Gray	Bleached
Elaborate seed cotton cleaning—one lint cleaner						
Low	8.8	7.5–3.0	31	23	1.07	.99
High	8.8	8.1–4.0	37	32	1.17	1.07
Moderate seed cotton cleaning—one lint cleaner						
High	8.8	8.4–4.7	37	27	1.18	1.07
Very high	8.2	7.6–4.0	39	30	1.17	1.06

* Warp and filling respectively.

the moisture regains of the card sliver or the bleached and resin treated fabrics. Small differences in densities were observed among other lots, but their relations to ginning practices were less conclusive.

The percent of swelling with alkali, a test which had distinguished excessively heated from unheated lint in other cottons [7], in these samples was more closely related to the fiber fineness than to the ginning practice. The three excessively dried lots had slightly greater swelling than predicted from the relation between swelling and fineness values of the twelve lots. The effects of fiber fineness were observed also in the colors of fabrics and lint dyed with differential dyes. The three fabrics from cotton dried to the lowest moisture level dyed to greenish shades rather than to the red shade expected when heat damage is appreciable. The inversion in behavior was associated with fiber fineness, which had greater effects on the color than the heat drying.

The lint from four lots selected from extremes in levels of drying had equivalent values for degree of polymerization. Only one from the six bleached fabrics tested had a degree of polymerization sufficiently below that of the others to indicate a possible cellulose damage from heat, even though the cellulose was degraded by scouring and bleaching. Microscopical examination indicated that heating had been insufficient to cause distinguishable differences in swelling characteristics of the cell wall. Although mechanical damage to cell walls was evident in several samples, the relation to the ginning practices was inconclusive.

The "acceptability rating" of the fabrics for print cloth outlets, reported by Faught [12], ranked as unsuitable five dyed fabrics from elaborate seed cotton cleaning, three of these being from cotton dried to the lowest moisture level. However, the fabric with the lowest rating was produced from lint of moderate seed cotton cleaning, very high moisture, and one lint cleaner. A comparison of these acceptability ratings with fiber fineness, given in Table II, shows that only one of six dyed fabrics from cotton with micronaire units of 4.4–4.6 was suitable while five of those with micronaire units of 4.7–4.8 were suitable for usual print cloth outlets. The only unsuitable fabric from lint of higher micronaire unit group had been made from lint given the most extreme drying and seed cotton cleaning practices.

In general, the strengths of the resin treated fabrics (Figure 1) followed those of the gray and

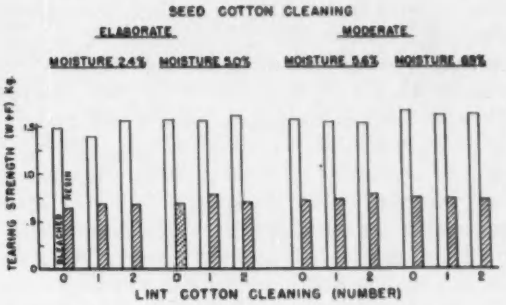

Fig. 2. The tearing strengths for warp and filling of the bleached and resin treated fabrics made of lint from the twelve combinations of ginning practices.

bleached. The filling strengths of the resin treated and the bleached averaged 78% of those of the warp, even though a 52% loss in strength was observed after resin treatment. The differences among strengths of resin treated fabrics for combinations of ginning practices were less than those in either the gray or bleached. For fabrics of the two moisture level groups in elaborate seed cotton cleaning, 2.4 and 5.0%, the percentage differences in their average strengths were 10% in the gray, 8% in the bleached, and 5% in the resin treated. Moisture levels were high for lint of both groups of moderate seed cotton cleaning, and differences in fabric strengths were negligible. While bleaching and resin treatments both reduce strength, the chemical processes also decreased the percentage differences between strengths of the fabrics.

The tearing strengths for the bleached and resin treated fabrics are given in Figure 2. Small differences were observed in their tear resistance in warp and filling directions, but these could not be associated with the ginning practices. In the bleached fabrics the tearing strength for filling was 77% of that for warp, while in the resin treated the filling was 66%. The 54% loss in tearing strength from resin treatment is slightly greater than the loss observed in the breaking strength. However, in general, tearing strengths of both the bleached and resin treated fabrics followed trends in breaking strengths. The relation of tearing strength to ginning practice is much less in the resin treated than in the bleached.

The flexing and abrasion cycles to rupture (Stoll abrader) for the bleached and resin treated fabrics are given in Figure 3. The pattern of results during flexing and abrasion were appreciably different from

their patterns in breaking or tearing. Among the bleached fabrics, the filling required on the average about 10% more cycles to rupture than did the warp, whereas the reverse was true for the resin treated; the warp required about 13% more than the filling. In general the cycles to rupture of the gray fabrics followed the order of their breaking strengths in both warp and filling directions. The results for gray fabrics are not included, since sizing and waxes are known to affect the cycles to rupture. After the fabrics were bleached, the cycles to failure were about 25% of those for the gray, but fabrics of the lower breaking strengths endured flexing as well as the stronger. The pattern of flexing behavior in relation to ginning practice leads one to conclude that embrittlement of fibers in the weaker fabrics caused by gin drying was temporary or that other factors were more important than embrittlement in the bleached fabrics.

As is generally found, the resin treatment affected the cycles to rupture much more than it affected either the breaking or tearing strengths. Resin treatment reduced cycles to rupture to about 34% of that for the bleached. The one fabric from cotton dried to the lowest moisture regain (1.7%) endured the least number of flexing cycles. However, two resin treated fabrics from cottons dried to that moisture level endured flexing as well as five fabrics from cottons dried to other moisture levels.

Properties of laundered fabrics have been used as measures of differences in their service life. The gray fabrics laundered included the weakest, an average, and two fabrics rated as the most and least desirable respectively for use as print cloth. These four fabrics were processed from lint from each combination of seed cotton cleaning and drying practices and cleaned with only one lint cleaner. The four gray and the corresponding bleached fabrics were given 50 repeat washings with a commercial detergent and chlorine bleaching solution in a home type washer and dryer. In Table III are given, in the order of their description, the fabric shrinkages, percentage loss in breaking strengths, and their tearing strengths.

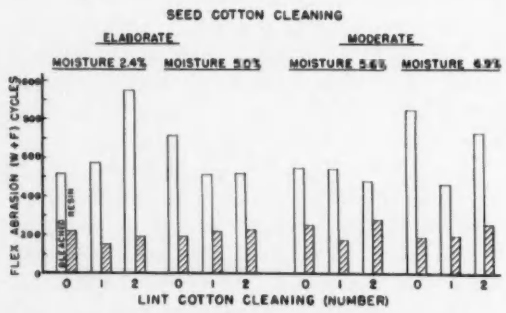

Fig. 3. The flexing and abrasion cycles to rupture for warp and filling of the bleached and resin treated fabrics made of lint from the twelve combinations of ginning practices.

The shrinkages in the gray fabrics were found to be slightly greater than those for the bleached. In the warp and fillings for the gray fabric, shrinkages were essentially equal; however, the bleached showed more shrinkage in warp than in the fillings. These differences in the bleached are evidence of stretching effects after the peroxide bleaching rather than the effects of ginning practices.

The breaking strengths of all fabrics were reduced by the launderings but not by equal amounts. The average loss in strength for the gray fabric was 36%, while that for bleached was 28%. This difference of 8%, which approximated the difference between the gray and bleached fabrics before laundering, equalized the strength of gray and bleached in the laundered fabrics. Further equalization occurred in the weak and strong fabrics. The loss in strength of the weak (gray and bleached) was less than that for the stronger fabrics. These changes with laundering caused further strength equalizations in sufficient amounts that differences among strengths for the eight laundered fabrics were too small to be significant.

The tearing strengths as measured with the Elmendorf method [1h] showed larger changes with laundering than observed in their breaking strengths. While the laundering caused a 75% decrease in tearing strength, differences found in the gray fabrics were evident in these fabrics after the laundering. The weak fabric both as gray and bleached had a slightly lower tearing strength after laundering. Also, the laundered bleached fabrics had tearing strengths below those of the gray.

Summary and Conclusion

Fabrics made from cottons dried to the lowest moisture level in combination with elaborate seed cotton cleaning were slightly weaker at three stages studied: gray, bleached, and resin treated fabrics. At a comparable moisture level of drying (5–6%) the breaking strengths of fabrics for elaborate and

moderate seed cotton cleanings were equivalent. The effects of lint cleaners were very inconclusive.

The degree of polymerization was reduced by scouring and bleaching by about equal amounts for the four combinations of practices tested. The density of cellulose of the bleached fabrics was slightly greater for the three excessively dried cottons; however, the effects of molecular changes were not detected in moisture regains, flexing and abrasion, or resin add-on. Moisture regains were essentially equal in the card sliver, in the bleached, and in the resin treated fabrics. At standard conditions, the regains were lowest in the resin treated fabrics and highest in the card sliver.

Alkali swelling percentages indicated differences associated with fiber fineness of the lints from several combination of practices. Drying effects were very small in alkali swelling data for the three overdried lots. Differential dyeings of lint and fabrics produced colors associated with fiber fineness rather than ginning practice.

The response of fabrics to resin treatment was considered equal. Resin treatment reduced appreciably the tensile and tearing strengths and flexing and abrasion resistance from that of the bleached. The percentage difference between fabrics for each of the properties was usually less after the resin treatment.

The lints from seed cottons dried to the low moisture level (2–3%) and subjected to cleaning practices produced appreciably lower quality fabrics than those dried to the higher moisture levels (5–7%). Measurements on the physical properties of the lower quality fabrics were usually below those of the better fabrics. The effects of ginning practices appear to be less on the cellulose than on the fiber or fabric properties. The maximum differences among fabrics from lint of the different ginning practices are found in the gray. Bleaching, resin treating, and laundering decrease but do not eliminate all differences found in the gray fabrics.

Acknowledgment

The fabrics were furnished by the Marketing Research Division of the Agricultural Marketing Service in cooperation with the American Cotton Manufacturers Institute, National Cotton Council, and Institute of Textile Technology. The authors wish to express their appreciation to Milton J. Hoffman for scouring and bleaching the fabrics, to Richard L. Arceneaux for resin treatment, to Anna T. Moore and Ines V. deGruy for microscopical examinations, to Samuel M. Stark, Jr. for measurements of degree of polymerization, to William G. Sloan for differential dyeing, and to Emilie H. Nott for fabric tests.

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Panel Discussion

Cotton Quality Evaluation

Chairman:—GEORGE S. BUCK, JR., National Cotton Council

The 1958 Ginning-Spinning Test

Cotton Selection and Ginning Conditions
VERNON P. MOORE
National Cotton Council

Effects on Fiber Properties
JOHN E. ROSS
United States Department of Agriculture

Mill Processing Conditions
JOSEPH L. DELANY
Joanna Cotton Mills Company

Test Results
JOHN E. ROSS
United States Department of Agriculture

*Effects on Finished Fabrics
JAMES N. GRANT
Southern Regional Research Laboratories

Pilot Spinning Laboratory
WILLIAM T. PENTZER
United States Department of Agriculture

* This paper appears on p. 751. The others will be published in a report by the United States Department of Agriculture.

Letters to the Editor

Radiation Polymerization of Acrylonitrile Onto Cotton

Southern Regional Research Laboratory [1]
New Orleans, Louisiana
May 21, 1959

To the Editor
TEXTILE RESEARCH JOURNAL

Dear Sir:

In the course of investigations involving the determination of the effects of gamma radiation on cotton cellulose [1, 3, 4] and on polymerization of vinyl monomers [2], a technique for the application, or possibly grafting, of large, controlled quantities of polyacrylonitrile onto cotton has been developed. Acrylonitrile monomer was uniformly applied to purified 7/3s yarn, Deltapine cotton, and then polymerized by gamma radiation from cobalt-60. The yarns were extracted overnight by N,N-dimethyl formamide at 25° C. to remove any monomer and soluble or loosely bound polymer. Raw yarns were also similarly treated to determine the effects of radiation polymerization of monomer onto raw cotton.

As shown in Table I, by use of aqueous $ZnCl_2$ as the solvent relatively large quantities of acrylonitrile monomer could be applied to the raw yarns and radiation polymerized onto the raw cotton.

[1] One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

TABLE I. Effect of Reagent Concentration on Radiation Polymerization of Acrylonitrile onto Raw Cotton at a Dosage of 10^6 Roentgens

	$ZnCl_2$, 75%			Acrylonitrile, 31.7%		
	Acrylonitrile, %			$ZnCl_2$, %		
Property of yarn	20	31.7	40	65	75	80
Polymer nitrogen, %	2.3	4.8	4.8	0.3	4.8	7.5
IP-4 Breaking strength,* lb.	8.5	8.1	8.4	8.8	8.1	8.0

* IP-4 breaking strength of untreated, raw yarn, 9.5 lb.; samples water washed to remove monomer.

TABLE II. Effect of Radiation Dosage on Polymer Add-On and Properties of the Purified Yarn. Treating Solution: Aqueous $ZnCl_2$, 80%; Acrylonitrile, 31.7%

Dosage, $\times 10^6$ roentgens	Polymer nitrogen, %	Polymer add-on*, %	IP-4 Breaking strength, lb.	Elongation at break, %
Purified yarn†	0.03	0.11	9.8	10.2
0.0‡	0.02	0.08	9.7	11.4
0.2	1.2	4.5	9.6	10.9
0.3	2.1	8.0	8.6	9.6
0.4	3.7	14	9.1	12.7
0.6	4.6	17	9.3	15.6
0.7	6.1	23	9.0	17.8
0.8	6.8	26	9.5	16.6
1.0	6.5	25	9.3	19.2

* Calculated from nitrogen content.
† Untreated, unirradiated yarn.
‡ Treated, unirradiated yarn.

The amount of polymer add-on and properties of the purified yarn could be controlled by varying the radiation dosage, as shown in Table II.

The results are particularly interesting relative to the preparation of chemically modified cottons. There was only a slight decrease in breaking strength, a significant increase in elongation at break, and a large amount of polyacrylonitrile bound to the purified cotton yarn. Results of a detailed study will be published.

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JETT C. ARTHUR, JR.
ROBERT J. DEMINT
WILBUR F. MCSHERRY
JULIAN F. JURGENS

An Investigation of Inorganic Salts and Oxides as Finishes for Cotton

College of Household Arts and Sciences
Texas Woman's University
Denton, Texas
May 15, 1959

To the Editor
TEXTILE RESEARCH JOURNAL

Dear Sir:

In an investigation of the use of inorganic compounds as finishes for cotton fabrics, 74 compounds selected from various groups in the periodic chart were screened systematically. The finishes were applied to 9 × 72-in. specimens of 4-oz. muslin;[1] the treated fabrics were tested for strength, abrasion resistance, water repellency, stability to weathering, mildew and rot resistance, stability to actinic degradation, thermal stability, fire resistance, resistance to aging in the oven, and the retention of the finish to leaching and to laundering. Full particulars with regard to processing, methods of testing, and evaluation can be found in an Agricultural Research Service Bulletin soon to be released by the U.S.D.A. Southern Utilization Research and Development Division.[2]

Many compounds were found to improve one or more functional properties of the cotton fabric, and nine were considered of special promise: aluminum hydroxide (or hydrated oxide), beryllium oxide, cobaltous hydroxide (or hydrated oxide), cobaltous metaborate, lead hydroxide (or hydrated oxide), manganous oxide, manganous phosphate, manganous silicate, and nickelous phosphate.

The major findings with regard to these compounds as finishes for cotton are summarized below.

Beryllium oxide, aluminum hydroxide, nickel phosphate, manganese silicate, phosphate, and oxide improved the resistance of cotton fabric to outdoor weathering. All of these finishes also increased the resistance of cotton to atmospheric contaminants. Of these finishes, the beryllium and aluminum compounds did not discolor the fabric. Fabrics treated with aluminum hydroxide, lead hydroxide, or manganese oxide passed the 45° angle flammability test. Fabric treated with the lead compound with a 15% add-on passed the vertical bunsen test. Some improvement was noted in the thermal stability of the cotton fabric when treated with lead hydroxide, manganese oxide, or manganese silicate. In addition, some of the compounds imparted a good degree of water repellency.

Cotton fabrics treated with cobaltous hydroxide or cobaltous metaborate showed very good resistance to weathering and to mildew and rot resistance. Both showed resistance to atmospheric contaminants, and the latter also displayed good water repellency. These compounds were believed to warrant additional attention in a practical field trial.

In addition to the evaluation of the 74 compounds, The ARS Bulletin contains a review of the literature on the use of inorganic compounds as finishes for cotton.

RAMON M. ESTEVE, JR.
GEORGIA ELLEN WRIGHT
PAULINE BEERY MACK

[1] 56 × 56 count, 2-ply yarn 1⅛-in. Mississippi Delta cotton.
[2] Southern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture, New Orleans 19, Louisiana.

Book Reviews

Handbook of Chemical Microscopy, Vol. I, Third Edition. Clyde W. Mason. New York, Wiley, 1958.

Reviewed by A. N. J. Heyn, The Clemson Agricultural College, Clemson, South Carolina

This excellent book has long been recognized as the standard work on the subject, and the appearance of a new third edition of the first volume, dealing with the basic principle and use of the instruments and physical methods for the study of chemical problems, is most welcome.

The new edition does not basically differ from the previous one, but many revisions and additions have been made and some new experiments are described. The organization has been improved by a clearer subdivision of sections; the section on "The Relations of Optical Properties to Structure of Aggregates and Crystals" is presented as a separate chapter.

The sections on ultramicroscopy of colloids, on particular size measurements, index ellipsoid and Millers indices, and various other ones have been expanded. New sections have been added on phase and interference microscopy, flying spot microscopy, and microradiography. An entirely new chapter has been added on electron microscopy "for the nonpractitioner."

A very useful new feature which will be highly welcomed by all chemical microscopist is the addition of a color chart of polarization colors, a hard-to-obtain item. Also, the addition of several new text figures on crystal systems and a few good photomicrographs (e.g., of the polymorphs of sulfur; very useful) is very valuable.

It is hoped that a new edition of the second volume of this standard work will soon follow.

Elementary Statistical Physics. Charles Kittel. New York, Wiley, 1958. 228 + ix pages. Price $8.00.

Reviewed by James H. Wakelin, Textile Research Institute, Princeton, New Jersey

This short summary of statistical physics, based on lectures given by Professor Kittel at the University of California, is divided into three parts: Fundamental Principles of Statistical Mechanics; Fluctuations, Noise and Irreversible Thermodynamics; and Kinetic Methods and Transport Theory. In the first part, topics have been carefully chosen in the order of their treatment to illustrate the method of ensembles developed by Gibbs; in this method the time average of a physical quantity of a single system is replaced by an average of the quantity at a fixed time taken over all of the systems comprising the ensemble. The *microcanonical ensemble* appropriate to *isolated, conservative* systems is introduced and applied to the calculation of the entropy of a perfect gas. The *canonical ensemble* in which subsystems of the ensemble are permitted to *exchange energy* is then constructed and its thermodynamic functions such as entropy, energy, and Helmholtz free energy are calculated. The development of Maxwell's velocity distribution and the principles of equipartition of energy illustrate the power and utility of the canonical ensemble. Finally, by permitting the subsystems of the ensemble to *exchange energy and particles*, the *grand canonical ensemble* is developed and the grand partition function for this ensemble is used to calculate the thermodynamic properties of a perfect gas and to develop the well-known expressions for the Fermi-Dirac and Bose-Einstein distributions and the frequency distribution of energy in the Planck radiation field. The first part ends with a brief discussion of the concept of negative temperatures characteristic of systems in which the higher energy state is more densely populated than the ground state. Kittel points out that resonance experiments performed on nuclear spin systems (nuclear magnetic resonance) or on electron spin systems (electron paramagnetic resonance) at negative temperatures actually stimulate resonance *emission* rather than absorption of radiation. This technique is used in radio frequency amplifiers as a first stage of amplification of very weak radar and radio astronomy signals; these devices are called Masers (microwave amplification by stimulated emission of radiation).

The second part starts with an introduction to the field of noise by considering (1) energy fluctuations in a canonical ensemble and then calculating the fractional energy fluctuation for a perfect gas

and for a solid at low temperatures and (2) concentration fluctuations in a grand canonical ensemble and calculating the fractional fluctuation for a perfect classical gas and for the Fermi-Dirac and Bose-Einstein statistics. After a summary treatment of the Fourier integral theorem and the general methods used in stochastic processes, the Wiener-Khintchine theorem is discussed relating to the power spectrum of a random process and its correlation function. Consideration is next given to the Nyquist theorem for the quantitative evaluation of the thermal noise of a system in equilibrium. This theorem is important, since it provides a method of calculating the signal-to-noise ratio of electronic equipment. The treatment of Brownian motion illustrating fluctuations due to thermal agitation leads to the Fokker-Planck equation describing the time development of a stochastic process useful in determining the approach of a system to statistical equilibrium. Finally, the Onsager reciprocal relations are briefly discussed in the treatment of irreversible processes and applied to the transport of electrical charge and energy in a homogeneous conductor.

In the third part Professor Kittel treats the theory of detailed balance and illustrates with several applications such as the determination of spins of fundamental particles, the Einstein derivation of the Planck radiation law, the photoionization of an atom, and the radiative recombination of electrons and holes in a semiconductor. The kinetic method is applied to nuclear spin relaxation in a metal; the Boltzmann transport equation is then developed and illustrated by application to the electrical and thermal conductivity of an electron gas. Following a discussion of the Kramers-Kronig relations, which permit finding the real part of the response of a system if the imaginary part is known as a function of the frequency, brief attention is given to transport theory for rarified gas systems.

The book is highly recommended as an introduction to the fundamental concepts of the Gibbs statistics; the material is clearly and thoughtfully presented and the choice of topics and exercise problems provide a well organized guide for classroom use. The book performs two useful purposes: it treats a wide variety of topics in statistical physics in a concise manner and it brings together in one volume parts of the field which are not normally included with the more usual gas and radiation statistics. For a deeper understanding of many of the topics, however, the serious reader will have to refer frequently to the classic works of Gibbs, Boltzmann, Lorentz, Tolman, and others, as well as to the more recent literature. For most of the subjects no extensive mathematical background beyond the ability to understand partial and total differentiation is required of the reader. Sections demanding a detailed knowledge of quantum mechanics carry a special designation and their omission does not prevent the reader from gaining a good introduction to the classical principles underlying statistical physics.